Africa Research in Sustainable Intensification for the Next Generation

Sustainable Intensification of Key Farming Systems in the Sudan and Guinea Savannas of West Africa

Technical Report,
01 April 2021 – 30 September 2021

Submitted to
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The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-in-development projects supported by the United States Agency for International Development (USAID) as part of the U.S. Government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING is creating opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment.

Africa RISING appreciates support from the American people delivered through the USAID Feed the Future initiative. We also thank farmers and local partners at all sites for their contributions to the program.

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Partners and their roles

Name	Abbreviation	Ghana	Mali	Role/responsibility
Government Ministries & Entities				
Ministry of Food and Agriculture	MoFA	+		Scaling-out SI technologies and establishment of R4D platforms
Ministry of Health (Ghana Health Services)	MoH (GHS)	+		Household nutrition R4D with UDS and IITA; Assist with training of women's groups on nutrition education, data collection, and compilation of reports on activities
Ghana Irrigation Development Authority	GIDA	+		Potential scaling partner for irrigation technologies with IWMI
Veterinary Services Division	VSD	+		Animal health, capacity building community health workers with Animal Research
Institut d'Economie Rurale	IER		+	Socioeconomic and on-farm studies with ICRISAT
Regional Direction of Agriculture in Sikasso	DRA-Sikasso		+	Scale-out provision of secondary data on socioeconomics
Academic/National Research Institutions				
University for Development Studies	UDS	+		Research on livestock nutrition and human nutrition, graduate training, and R4D
Science and Technology Policy Research Institute	STEPRI	+		Policy review and analysis
Institut Polytechnique Rural de Formation et de Recherche Appliquée Katibougou	IPR-IFRA		+	Polytechnic for rural education and applied research
Kwame Nkrumah University of Science and Technology	KNUST	+		Graduate student training, research on soil water dynamics
Animal Research Institute	ARI	+		R4D on livestock production (sheep and goats) with ILRI
International Research Institutions				
International Crops Research Institute for the Semi-arid Tropics	ICRISAT	+	+	Sorghum/millet–groundnut R4D with IITA and SARI
International Food Policy Research Institute	IFPRI	+	+	Surveys, and monitoring and evaluation
The World Vegetable Center	WorldVeg	+	+	Lead R4D on vegetable production systems
International Institute of Tropical Agriculture	IITA	+	+	Project coordination and R4D research on cereal–legumes.
International Livestock Research Institute	ILRI	+	+	Lead R4D on livestock, especially ruminants

Name	Abbreviation	Ghana	Mali	Role/responsibility
International Water Management Institute	IWMI	+		Lead R4D on water management
Wageningen University, The Netherlands	WUR	+	+	R4D on farming systems and graduate training
International Center for Tropical Agriculture	CIAT	+		Research on land and soil management
Non-governmental Organizations				
Centre d'Appui a l'Autopromotion pour le Développement	CAAD		+	Scaling out groundnut technologies. Assisting the implementation of animal health and fattening program by ILRI and IER.
Fédération Nationale pour l'Agriculture Biologique et Équitable	FENABE		+	Scaling-out, capacity building, community mobilization, on-farm research
Association Malienne d'Eveil et de Développement Durable	AMEDD		+	On-farm field trials and household nutrition studies with ICRISAT
Le Groupe de Recherches d'Actions et d'Assistance pour le Développement Communautaire	GRAADCOM		+	Scaling out groundnut technologies. Assisting implementation of animal health and fattening program by ILRI and IER.
CARE International	CARE-MALI		+	Disseminate Africa RISING validated technologies in 12 watersheds that constitute 82 villages in the Mopti region
Private Organizations and Development Projects				
Community-based Organizations	CBOs	+	+	On-farm implementation of R4D activities
Peace Corps	Peace Corps	+		Introduce Africa RISING technologies to communities they work in
Seed Producers Association of Ghana	SEEDPAG	+		Seed production and training of farmers for quality declared seed
WorldCover	WorldCover	+		Indexed based agricultural insurance, co-sharing of farmers in some communities for synergies
Feed the Future Innovation Labs				
Sustainable Intensification Innovation Lab	SIIL	+		Co-share materials, concepts, and approaches to conducting research, e.g., use of the Sustainable Intensification Assessment Framework
Soybean Innovation Lab	SIL	+		Sharing knowledge and approaches towards post-harvest mechanization in communities

Name	Abbreviation	Ghana	Mali	Role/responsibility
Innovation Lab for Legume Systems Research	ILLSR	+		Acting as the liaison between the Mission Office and the Innovation lab and conducting joint research activities
Innovation Lab for Small Scale Irrigation	ILSSI	+		Co-location of sites with Africa RISING work and sharing knowledge, approaches, sites, and personnel, e.g., with IWMI

Summary

This report provides feedback on implemented work and achievements of partner activities mapped out against outputs and outcomes in the Phase 2 project log-frame for the period 01 April 2021 – 31 September 2021 for the Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) project in West Africa (Ghana and Mali).

***Ghana and Mali cross-country summary*:**

1. **A Handbook for Practitioners in West Africa:** A team of co-authors drawn from Africa RISING project partners are writing up content. The current draft can be accessed here: https://docs.google.com/document/d/1HaMpUNUxNxiu8yLDvP2jCZ-gXiHwkGRynMd2J3Q67Jw/edit#

2. **Joint harmonization papers:** After a successful Program wide exchange visit in June 2019, a series of joint harmonization papers were drafted amongst partners. The six manuscripts are on landscape processes, livestock, mechanization, nutrition, agricultural scaling, and water management and are at different stages of development. Three manuscripts have undergone internal peer review and are in a finalization process before submission for publication.

Implemented research by country:

In Ghana:

i. Activities in Ghana build on previous efforts reported in the past reporting cycle, such as the agronomic trials on cowpea living mulch combined with environmental measurements such as soil and water measurements and fertilizer trials of blends and compound types of forage-legume intercrops, as well as livestock activities. The sub-activities have completed fieldwork and are in a writing phase for the deliverables.

ii. Discussions with the Sustainable Intensification Innovation Lab on the i-REACH concept proceeded smoothly. There has been an agreement that the Africa RISING Technology Parks in the North will be used as i-REACH pilot sites for the Guinea Savannah Zone. Dr. Lamien from CORAF will be visiting these sites in December together with CSIR Staff from Kumasi. This will serve as an opportunity to scale Africa RISING interventions to broader audiences.

iii. A guidance manual on soil and water conservation measures has been developed for Agricultural extension agents.

In Mali:

i. Demonstration plots of three forage species (*Brachiaria ruziziensis, Mucuna pruriens,* and *Vigna unguiculata var. Sankaranka*) were established at the technology park in M'Pessoba, Koutiala district, and Madina, Bougouni district. This is follow-up work on demonstration plots that ranged from 225 m2 to 600 m2 which were established in July 2020. Agronomic data such as date of germination, plant height and number of leaves per plant at monthly intervals, and total biomass were collected. Data collected will be appended to the previous data collected in 2020.

ii. Work conducted on scenario analyses revealed that incremental improvements in agricultural practices (e.g., intercropping, crop-livestock integration) were insufficient to lift a considerable portion of the population above the living income and food self-

sufficiency thresholds. Our analysis confirmed expected trade-offs between increasing agricultural productivity and environmental objectives.

Introduction

The United States Agency for International Development (USAID) is supporting multi-stakeholder agricultural research projects to sustainably intensify key African farming systems as part of the US government's "Feed the Future" initiative to address global hunger and food security issues in sub-Saharan Africa (SSA). IITA is the lead institute for developing and implementing the Sudan-Guinea savanna zone project of Africa RISING. The project primarily focuses on the maize/rice-legume-vegetable-livestock and sorghum/millet-legume-vegetable-livestock farming systems in the Guinea and Sudan savanna ecological zones of the West African region using northern Ghana and southern Mali, respectively, as representative implementation sites. Thus, technologies and practices developed from Africa RISING research at the project sites in Ghana and Mali to reduce poverty, food insecurity, and environmental degradation are applicable in other countries with similar biophysical and socioeconomic conditions within and outside the West African region—providing international public goods.

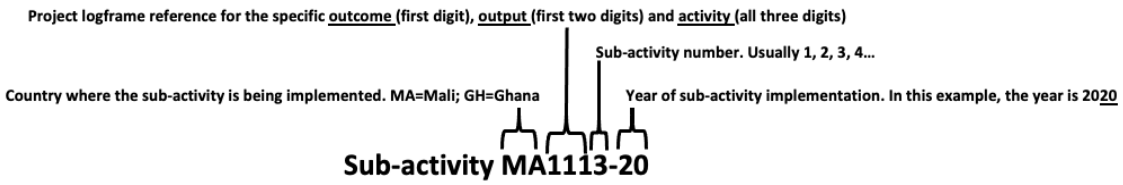
Phase 1 (1 October 2012–30 September 2016) of the USAID-funded Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) project in West Africa (WA) was implemented in 25 intervention communities in northern Ghana and nine villages in the Bougouni and Koutiala districts of the Sikasso Region in southern Mali under the title "Sustainable intensification of key farming systems in the Guinea-Sudano-Sahelian Zone of West Africa."

Phase 2 (1 October 2016–30 September 2021) of the WA project was launched in February 2017. Achievements and lessons from Phase 1 guide the implementation. The activities and sub-activities are mapped under four Outcomes in Africa RISING West Africa Project Phase 2 logframe. Thirty-four (34) sub-activities are implemented in the Ghana Workplan, while sixteen (18) are implemented in the Mali workplan. The distribution of the 52 sub-activities per outcome is as presented in Table A below.

Table A. Distribution of sub-activities per West Africa project logframe outcome

Country	Outcome 1	Outcome 2	Outcome 3	Outcome 4	Totals
Ghana	14	5	6	9	**34**
Mali	10	1	2	5	**18**
Totals	**24**	**6**	**8**	**14**	**52**

Each sub-activity in the report is preceded by a label code meant to help the reader gain context about the country of implementation, alignment with specific outcomes, outputs, and activities within the project logframe, and the relevant year of implementation. This label code is interpreted as shown below.



Linkages between activities, gender mainstreaming, capacity building, knowledge exchange, and dissemination are embedded within all sub-activity plans. Publication of research findings and better communication among research teams within and across countries continue to be a major focus.

This report presents progress on implementing sub-activities for the period 01 April 2021 through 30 September 2021. It builds on the technical report for the periods 01 October 2020 through 31 March 2021.

Implemented work and achievements

Outcome 1: Farmers and farming communities in the project area are practicing more productive, resilient, and profitable and sustainably intensified crop–livestock systems linked to markets

Output 1.1: *Research products for more productive, intensive, diverse, profitable, and resilient crop (cereals, legumes, and vegetables); livestock (sheep, goats, cattle, poultry, and pigs), and integrated crop–livestock farming systems are identified and disseminated to farmers through development partners*

Activity 1.1.1: *Test and disseminate a combination of climate-smart crop varieties and agronomic practices to increase and sustain food and feed production*

Sub-activity GH1111-20: Follow-up on gender evaluation of cowpea living mulch intervention (Lead Institution: IITA)

In 2019, the Africa RISING gender team evaluated the cowpea living mulch intervention with male and female farmers. Data has been processed and analyzed. The activity proposed is a follow-up study with the following objectives: to validate the results of the 2019 study (specifically to seek clarification on labor roles) and to fill data gaps for the cowpea living mulch modeling paper. The data collection and quantitative analysis concerning the follow-up study for gender implications of the cowpea living mulch technology have been finalized. The overall analysis and write-up are still taking place and will be carried forward into the next workplan.

Sub-activity GH1112-20: Optimizing on-farm nitrogen (N) use efficiency under rainfed conditions in maize-based cropping systems (Lead Institution: IITA)

No specific activities took place during this reporting period. A manuscript has been planned to be published in December 2021.

The sub-activity will be carried forward as part of the i-REACH Innovation Research Extension Advisory Coordination Hubs (i-REACH) in Ghana's Northern and Upper East regions. i-REACH is a knowledge sharing and learning hub to demonstrate all cereal-legume-livestock technologies for farmers, extension agents, and policymakers.

Sub-activity MA1111-20: Evaluating crop simulation models using different fertility sources and climate model outputs to improve the productivity of sorghum (Lead institution: ICRISAT)

Different fertilizer sources which combined both organic (cow and poultry manure) and inorganic fertilizer application on three sorghum varieties (Soumba, Fadda, and Tieble) were evaluated with the target of increasing productivity (grain and stover yield). Over the three (3) cropping seasons (2017 to 2019), results revealed that both grain and stover yield varied significantly among varieties, different fertilizer treatments, and sources applied across three agro-ecological sites (Bamako, Bougouni, and Koutiala). This work has been demonstrated on farmer field days as a way of increasing dissemination. This sub-activity was carried forward to 2020, where more attention was paid to incorporating rainfall data and soil characteristics. The team is currently writing up a manuscript on key findings of this work.

Sub-activity MA1112-20: Understanding soil fertility management in cereal cropping systems in southern Mali (Lead institution: ICRISAT)

This sub-activity was directed at understanding nutrient dynamics and generating nutrient adding and nutrient saving technologies. Nutrient dynamics from the farm to the field have been monitored, composting and its application in a micro-dosing technology was practiced at the technology parks and farmers' fields. Cattle-corralling has been studied to evaluate the productivity of dual-purpose sorghum. The team has drafted a manuscript that is going through an internal review process before submission for Journal publication.

Sub-activity GH1113-20: Assessing the potential for a combination of local Napier grass fodder species and pigeon peas for improved soil health and ruminant productivity in the Guinea savannah zone (Lead Institution: UDS-Faculty of Agriculture)

This study took place in the IITA Africa RISING Technology Park in Duko in the Savelugu Nanton District of Ghana. The activity sought to investigate the fodder yield and nutritional value of Napier grass intercropped with Pigeon pea. A total of nine smallholder crop/livestock farmers comprising of six males and three females who were previously involved in this activity in the year 2019/2020 were selected for the second phase. A total of 36 plots were prepared and were assigned three treatments (Sole Napier grass, Napier grass intercropped with Pigeon pea, and sole Pigeon pea) with four replicates in a randomized complete block design. The farmers were each assigned four plots to undertake some management activities. At the beginning of the cropping season (June/July 2020), the field was cleared of weeds, and the previously established Napier grass was pruned to a height of 30 cm. Due to the erratic nature of the rainfall pattern, the sowing of Pigeon pea was delayed till August 2020. Weekly field monitoring was undertaken with the measurement of plant height and branch numbers going on alongside. Study results showed a weekly increase in plant height and number of branches in both sole Napier and intercropped with the sole Napier grass showing greater plant height and number of branches. On-going efforts include analysis and writing of the interaction of environmental components at the field level with the productivity data. The work on productivity, published as a journal article, can be accessed HERE.

Sub-activity MA1113-20: Testing adaptation of dual-purpose sorghum hybrids in Mali to diversify options for crop-livestock integration (Lead institution: ICRISAT)

In Mali, farmers use sorghum and millet as a staple food, especially in rural areas. With the continual increase of livestock and diminishing natural pastures, crop residues play an important role in animal feeding, especially during the dry season. Most farmers are using landrace residues as fodder, but the quantity and quality of this feed are limited/poor. This sub-activity was carried forward from last year and was implemented in the four technology parks in Mali with four new hybrids compared to Fadda (released hybrid used as dual-purpose) and a local variety. Hence, six dual-purpose hybrids were tested against a local variety (control) in Bougouni and Koutiala. Agronomic trials were established in 2019 and 2020 to parameterize dual-purpose sorghum varieties in APSIM and DSSAT models. Modeling efforts enabled the identification of major water stress scenarios affecting crop growth and development in sorghum production regions. They contributed to understanding the production risks of dual-purpose sorghum varieties. There is no new data collected during this Reporting period, but the econometric analysis is ongoing to derive viable recommendations for farmers and extension agents.

Six dual-purpose hybrids were tested against a local variety (control) in Bougouni and Koutiala. The grain yield varied from 4.4 t/ha to 5.8 t/ha in Bougouni and from 2.9 t/ha to 5 t/ha in

Koutiala (see table 1). Compared to the local variety used as a control, the yield advantage was 291% to 415% in Bougouni. In Koutiala, only the new hybrid ICSX 17651145:H (5 t/ha) showed a positive yield gain (10%) compared to the local variety (4.6 t/ha). In summary, the two hybrids ICSX 1765690:H and ICSX 17651145:H showed good grain and stover yields and were also well appreciated by farmers (between 64 and 76% of preference) both in Bougouni and Koutiala.

Table 1. Agronomic performance of dual-purpose sorghum hybrids

Zone	Variete	50%FL	GrY_t_ha	Pref%_G	FSY_t_ha	Grain yield advantage/ Local (%)	Grain yield advantage/ Local (%)
Bougouni	ICSX 1765505:H	82	5.4	40	22.4	378	28
	ICSX 1765690:H	85	5.8	76	25.6	415	45
	ICSX 1765232:H	79	4.4	51	24.1	291	37
	ICSX 17651145:H	86	5.7	74	18.3	409	4
	Fadda	80	5.4	61	22.8	380	30
	Local	93	1.1	17	17.6		
Koutiala	ICSX 1765505:H	84	4.1	57	25.1	-10	8
	ICSX 1765690:H	84	4.4	64	25.1	-3	8
	ICSX 1765232:H	84	2.9	41	23.9	-37	2
	ICSX 17651145:H	84	5.0	65	25.7	10	10
	Fadda	86	5.2	84	25.8	13	11
	Local	82	4.6	66	23.3		
P Value	*Entry*	*0.002*	*<.001*	*<.001*	*0.347*		
	Zone	*0.04*	*0.003*	*0.747*	*0.096*		
	Entry x Zone	*0.081*	*<.001*	*0.151*	*0.454*		
	LSD (5%)	*4.865*	*1.463*	*19.16*	*6.6*		

The hybrid ICSX 1765232:H is the earliest maturity in the two zones and exhibited good grain and stover yields, especially in Bougouni. It was also selected by 51% of farmers, while the local variety was selected by only 17% of farmers in Bougouni (Figure 1).

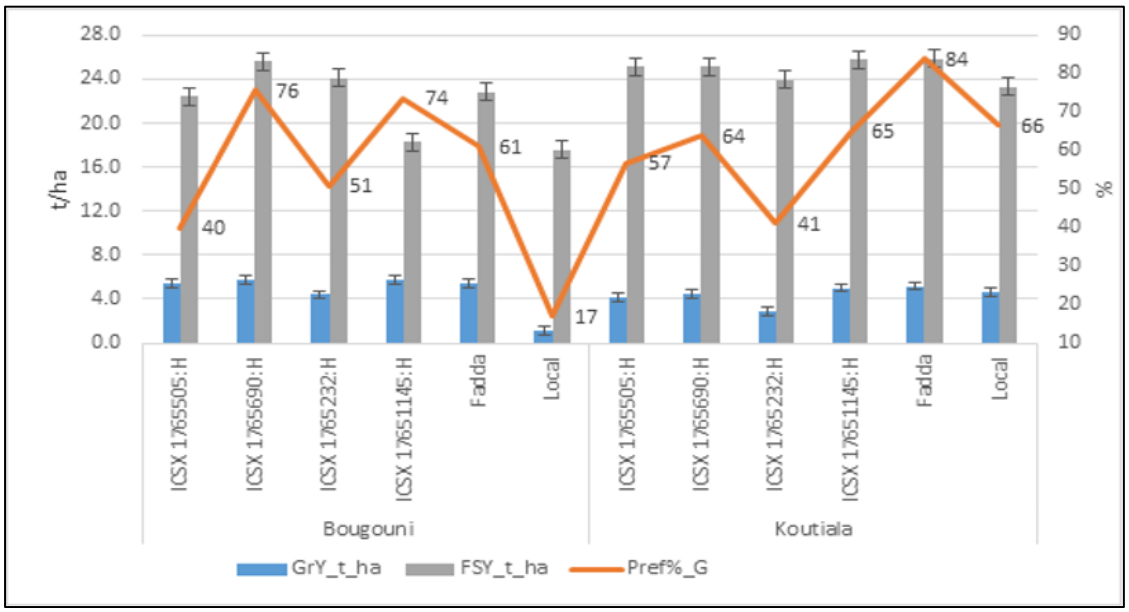


Figure 1. Grain and stover yields and framers preferences in Bougouni and Koutiala districts

Female and male farmers were asked to rate the varieties. Grain yield, stover yield, and farmers' preferences are positively correlated. The preference of farmers (especially men) for a hybrid is mainly due to its high yield as the correlation between the global preference and grain yield is r = 0.63, and between grain yield and men, preference is r = 0.67. Fodder yield has also a positive correlation with farmers' preference (r = 0.21 for global; r = 0.23 for men and r = 0.14 for women) (Figures 3x and 4x).

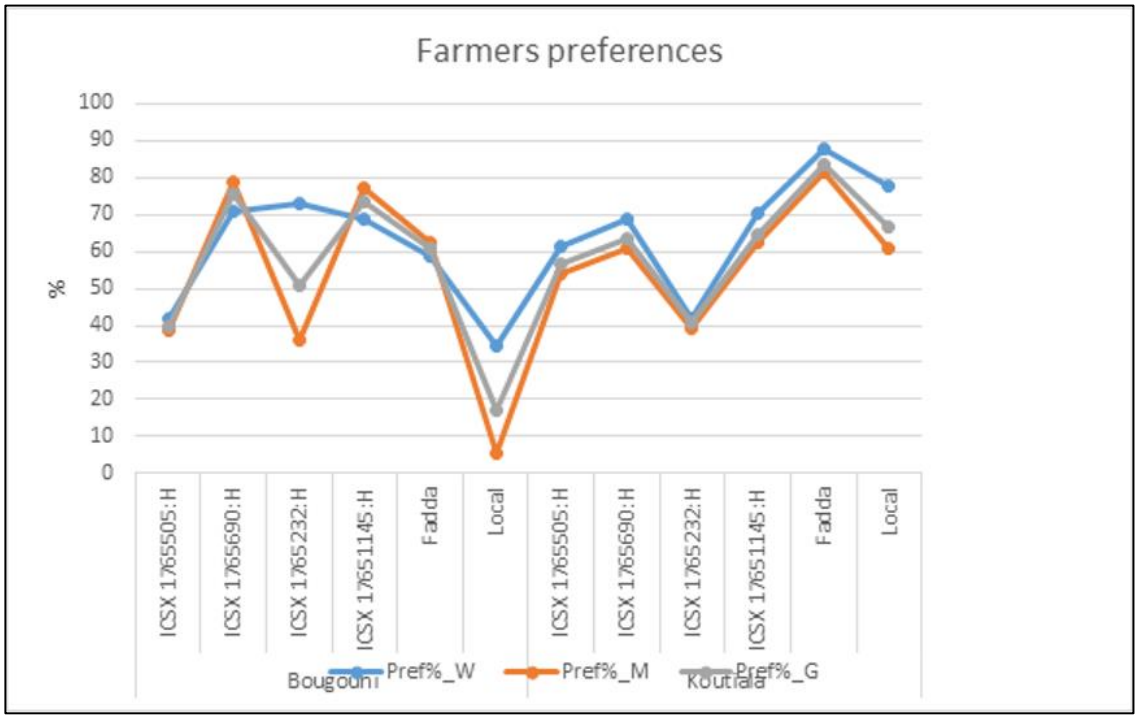


Figure 2. Grain and stover yields and farmers variety preference in Bougouni and Koutiala districts

For most hybrids, men's and women's preferences have the same trends (Figure 2), facilitating the selection strategy and meeting both needs. Men are more focused on yields (grain and stover), while women focus on yields and grain quality for household consumption.

This sub-activity will be carried forward to next year, although no new data will be collected. The economic analyses have not taken place yet, and these will inform about the recommendations to farmers.

Sub-activity GH1114-20: Use CCAFS' Climate-smart village approach to mainstream climate variability in the promotion and dissemination of Africa RISING SI interventions for sustained productivity and reduced risk in Ghana (Lead Institution: SARI)

This sub-activity aimed at identifying research products for more productive, intensive, diverse, profitable, and resilient crops (cereals, legumes, and vegetables); livestock (sheep, goats, cattle, poultry, and pigs); and integrated crop-livestock farming systems. It has disseminated relevant information to farmers through development partners in the intervention communities. For example, SARI is reaching out to various other initiatives to ensure visibility and impact at scale and is exploring potential linkages with farmer and women interest groups as candidates that can contribute to scaling out validated technologies and practices. SARI is also working directly with Esoko through CCAFS work, and this provides synergistic effort to the work that Africa RISING is doing.

This sub-activity aims to improve access and use of downscaled seasonal forecast and climate-smart agriculture technologies and practices (agro-advisories) by providing advice on agronomy, climate services, and market information via mobile phone and Esoko platform to farmers in the project communities.

The project partners are currently packaging information of validated innovations or technologies as evidence briefs/ fact sheets. They are establishing contact with potential development partners to share results from innovations that can be taken to scale.

Figure 3. Focus Group Discussions at Goriyiri, Nadowli district (A) and at Gia, Kasssena Nankana district, Upper East Region (B). Photo credit: Benedict Boyubie/IITA.

MA1114-20: Evaluate and disseminate technologies to control vegetable pests and diseases, reduce post-harvest losses and improve human nutrition (Lead: WorldVeg)

This sub-activity introduces, evaluates, adapts, and disseminates the various disease and pest management, post-harvest technologies, and practices. It is comparable to sub-activity GH1115-20.

Screening for pests and diseases

Twenty-four tomato and sixteen pepper entries of WorldVeg and other locally used varieties were tested in the technology parks for adaptability, potential yield, and resistance to diseases and pests in two sites in Mali (Bougouni and Koutiala). A nursery was established in both test sites, and seedlings were raised. Each accession of both tomato and pepper was planted in the field in two rows of 12 plants each (24 plants/plot) with a randomized complete block design replicated three times. Agronomic data (plant height, time to 50% flowering, time to 50% fruiting and maturity and yield), pest and disease (percentage of plants showing disease or insect pest symptoms) have been collected. Data were subjected to ANOVA using GenStat software (VSN International). Means were separated using Tukey's 95% confidence intervals in GenStat.

The most common plant diseases observed in tomato production during the 2020-2021 dry season growing season in Koutiala and Bougouni of Mali included: tomato yellow leaf curl diseases (TYLCD), bacterial wilt, early blight, and bacterial leaf spot. However, there were no significant differences among the tested tomato entries and varieties on these different diseases. Insect pests such as tomato fruit borer (*Helicoverpa armigera*) and whiteflies were major problems during the growing season in both locations. In Koutiala, tomato popular inbred line UC82 was one of the most TYLCD affected followed by AVTO170 7, and FORMOSSA was the most bacterial wilt disease affected variety. However, in Bougouni, there was no high disease pressure observed except the variety Rio-Grande was considerably affected by bacterial wilt diseases. Several of the tested tomato entries were resistant to the diseases encountered, and tomato farmers can have a good choice of tomato varieties. The most promising varieties are Keneya, AVTO1717, and VIO43614 (yield >30T/ha) in Koutiala, and the varieties AVTO1718, AVTO1719, and AVTO1729 (yield >30T/ha) performed best in Bougouni.

The diseases most observed in the pepper trials in Koutiala were viruses (*Begomoviruses*) (Figure 4), bacterial wilt, and early blight. Bougouni bacterial wilt (Figure 9x), bacterial leaf spot, and southern blight were recorded in addition to those diseases observed in Koutiala. However, there was no high disease pressure observed in both test locations.

Figure 4. Bacterial wilt Blight disease infected pepper plant in the pepper disease screening trial in Koutiala in 2021. Photo credit: Jean Baptiste Tignegre/World Vegetable Center.

The most promising pepper varieties in Bougouni and Koutiala are AVPP512 and Nisondia (yield >3.9T/ha). AVPP512 yielded 50% higher than the old variety Nafama (2T/ha).

Like in Northern Ghana, field days were organized in both places during which the qualities of the different varieties were discussed.

The second theme in this sub-activity concerns sacks gardening during the dry season. Sack gardening aims at reducing malnutrition for vulnerable people through vegetable production and consumption by women with no access to land or reliable water source for normal gardening. It involves recycled fertilizer bags as containers filled with soil and compost serving as plant substrate. It promotes space and water use efficiency and a diverse range of legume species grown in a confined space. Three to four cycles of production are possible annually. In the household, it appears as a source of food and ornamentals. Access is easy for all social categories in rural areas and urban and peri-urban farmers.

Methodologies

Fifty farmers in two districts (Bougouni and Koutiala) tested tomato, onion, Amaranth, cabbage, carrot, and vegetable cowpea, using 50kg-content recycled fertilizer sacks in the dry season. Twenty farmers in each district planted 25-30 vegetable seedlings of amaranth, African eggplant, tomato, onion, and carrot on the open top of the sacks (horizontal position). The field design was randomized blocks with four replicates in two technology parks across two locations (Bougouni, Koutiala). Each farmer tested two replicates of tomato, Amaranth, African eggplant,

onion, carrot. The planting dates were November 2020. Insect pests were controlled by spraying Neem oil. The intervention sites were the technology parks in Bougouni and Koutiala (Mali) 50 selected individual farmers in Bougouni and Koutiala districts.

The focus group discussion conducted in 2021 in Koutiala and Bougouni to study the beneficiaries' perception of sack gardens showed that 80% of women, 75% of men, 76% of youth, and 75.5% of the poorest are willing to adopt this technology. Sack gardens remain a tool to reduce malnutrition and are easy to access in terms of the close vicinity of their homes, space-saving, and the diversity of products.

Figure 5. A farmer in Bougouni at her vegetable sack garden. Photo credit: Jean Baptiste Tignegre/World Vegetable Center.

This sub-activity will be continued next year (2021-2022). Last year, the trials were visited twice by members of the national committee in charge of variety certification. The certification process requires two years of data. Apart from the trials, partnerships will be established with organizations in Koutiala and Bougouni to assist with the scaling process. Knowledge transfer and scaling will include the establishment of research for development plots to demonstrate the technologies. Seed Outgrowers will be linked to seed enterprises to improve farmers' access to seeds.

Sub-activity GH1115-20: Identification of major pests and diseases and management of vegetable crop species to preserve post-harvest product quality in Northern Ghana in the dry season farming systems (Lead Institution: WorldVeg)

This sub-activity aims to reduce post-harvest losses, avail healthy products and improve income by demonstrating adapted storage prototypes and processing technologies in the technology parks/lead hubs. Twenty-four tomato and 16 pepper WorldVeg accessions and varieties including locals for control have been tested for resistance to diseases and pests in one site in the Upper East region of Ghana. Agronomic data (plant height, time to 50% flowering, time to 50% fruiting and maturity and yield), pest and disease (percentage of plants showing disease or insect pest symptoms), and post-harvest fruit quality of tomato varieties (size, color, and firmness) have been collected and analyzed (ANOVA using JMP v15 or GenStat software). Tomato Yellow Leaf Curl Disease (TYLCD, early blight, and bacterial leaf spot were the most abundant diseases. Whiteflies and tomato fruit borer were the most common pests. There was a significant difference in the TYLDC disease recorded for the pepper varieties (ranging from 1-19.4% of plants affected) (see table 2). At the same time, there was no significant difference between the tomato varieties. There were no other significant differences recorded for the other diseases and pests. Significant differences in yield were recorded for both the pepper and tomato varieties.

Table 2. Disease Prevalence on pepper varieties.

Treatment	Yield	Virus	Early Blight	Bacterial Leaf Spot
AVPP0002	9.034de	5.556a	1.389a	4.17
AVPP1109	6.14abcde	4.167a	4.167a	16.67
AVPP1236	6.453bcde	2.778a	4.167a	6.94
AVPP1245	2.697ab	5.556a	5.556a	11.11
AVPP1346	6.36abcde	5.556a	2.778a	9.72
AVPP1602	4.601abc	4.167a	2.778a	2.78
AVPP512	6.372abcde	9.722ab	1.389a	4.17
AVPP514	2.552ab	6.944ab	6.944a	22.22
AVPP9703	10.255e	0a	4.167a	8.33
AVPP9813	7.587cde	2.778a	4.167a	6.94
BAFARIMA	2.193a	19.444b	12.5a	11.11
CO55	4.363abc	9.722ab	8.333a	20.83
NAFAMA	4.306abc	12.5ab	11.111a	16.67
NISONDIA	4.942abcd	9.722ab	12.5a	13.89
p-value	**0.001**	**0.001**	**0.028**	**0.08**

The separate analyses concerning diseases, pests, yields, and product qualities have been finalized. Yet, the results will be cross-linked and substantiated next year, which will enable adequate variety recommendations to farmers.

Sub-activity GH1116-20: Determine yield and post-harvest quality of vegetables as affected by improved soil and water management practices in the dry season in Northern Ghana (Lead Institution: WorldVeg)

The objective of this sub-activity is to determine an optimized manure application rate that increases tomato yield and preserves fruit quality during storage. The treatments were as follows: T1- Control (no soil amendment); T2: NPK15-15-15 fertilizer at recommended rate; T3: Manure at the recommended rate (five t/ha) and T4: NPK15-15-15 and manure fertilizer at half the recommended rates. The first harvest of tomatoes was done on 27 March 2021, and data has been recorded on the various parameters: Total number of fruits per plot, fruit weight, and the total number of plants bearing fruits per plot. Yield per plot will be computed and extrapolated for a hectare. Forty fruit samples were collected (ten each per treatment) and sent to the laboratory for quality analysis (Color, Total Soluble Solids, Titratable Acidity, and Vitamin C). The combination of NKP (15-15-15) and Manure fertilizer at half the recommended rate provided the highest yield of 24t/ha, which was significantly different (<0.001) from the other treatments (see table 3).

Table 3. Tomato yield from soil amendment trial in Nyangua, Northern Region, Ghana

Treatment	Mean
T1	6.32 a
T3	16.15 b
T2	18.03 b
T4	27.08 c
Mean	16.89
P (5%)	<0.001
CV (%)	16.7
LSD	S

P (5%): probability value with 95% confidence interval; CV (%): Coefficient of variation; LSD (5%): Least significant difference with 95% confidence interval

Fruit quality parameters were also analyzed at the lab to evaluate the effect of the different soil amendment practices on the different fruit qualities. Significant differences (>0.013) were recorded for the vitamin C component, with treatment T2 and T3 being significantly different but not different from T1 and T4. Treatment T3 recorded the highest vitamin C content of 8.03mg/20ml, while treatment T2 recorded the lowest of 4.67mg/20ml. No significant difference was recorded across the other parameters (TSS and TAA). In terms of color, a significant difference (>0.012) was seen in Hue Angle, with no difference recorded for Chroma. Treatment T4 recorded the highest dry matter content of 9.29%, with no significant difference from the other treatments (0.961) (Table 4).

Table 4. Quality characteristics of tomato fruit from soil amendment trial

Treatment	Dry Matter (%)	Chroma	Hue Angle (ho)	TSS (oBrix)	Vitamin C (mg/20ml)	TAA (g/l)
T1	8.72a	51.78a	46.74ab	6.37a	7.22ab	10.44a
T2	9.03a	45.12a	45.42a	5.87a	4.67a	10.14a
T3	9.11a	51.03a	52.35b	5.8a	8.03b	9.37a
T4	9.29a	48.09a	47.74ab	6.03a	5.82ab	9.39a
p-value	0.961	0.104	0.012	0.083	0.013	0.038

P (5%): probability value with 95% confidence interval; CV (%): Coefficient of variation; LSD (5%): Least significant difference with 95% confidence interval; TSS: Total Soluble Solids; TAA: Titratable Acidity

Soil samples have been taken, and the analyses will be finalized soon, which will allow for some more elaborate conclusions, which will feed farmer recommendations.

In addition, the study sought to determine the best storage option for fruits and vegetables in the ZECC (Zero Energy Cooling Chamber) that extends shelf life. The experiment on ZECC commenced on the 13th of March 2021 at both Northern Region (Doku) and Upper East Region (Nyangua) with tomatoes. Four varieties (Pectomech, Tropimech, UC82, and Local) were stored under four different storage methods; namely, fruits stored in ZECC (T1), fruits mixed with ash (1:2 w/w) and stored in ZECC (T2), fruits mixed with ash and stored at ambient conditions (T3) and fruits stored at ambient conditions (T4). The first round of the experiment ran for nine days, and the second round started on 23rd March 2021 and ended on 1st April 2021. Data such as Temperature and Relative humidity were recorded using data loggers. Data on fruit weight, fruit loss, and percent decay were also collected. Tomato fruits were sent to the laboratory on each sample day for quality analysis (Color, Total Soluble Solids, Titratable Acidity, and Vitamin C). Visual quality assessment was also done. The two rounds of results have been ranked by the farmers (see tables 5 and 6).

Table 5. Overall Visual Quality of Tomato Treatments

Treatments	Doku	Nyangua
	Highest score ranked	Highest score ranked
Tropimech mixed with ash and stored in ZECC (TZA)	5	4
Pectomech mixed with ash and stored in ZECC (PZA)	5	4
UC82 mixed with ash and stored in ZECC (UZA)	5	4
Local mixed with ash and stored in ZECC (LZA)	5	3
Lemongrass ash (LG)	5	-
Tropimech without ash and stored in ZECC (TZW)	5	3
Pectomech without ash and stored in ZECC (PZW)	5	3
UC82 without ash and stored in ZECC (UZW)	5	4
Local without ash and stored in ZECC (LZW)	5	2
Neem oil (NO)	4	-

*Score scale: 5. Excellent, essentially no symptoms of deterioration, 4. Good, minor symptoms of deterioration, not objectionable, 3. Fair, deterioration evident, but not serious, the limit of salability, 2. Poor, serious deterioration, the limit of usability, 1. Extremely poor, not usable.

Table 6. Physical Damage of Tomato Treatments

Treatments	Doku	Nyangua
	Highest score ranked	Highest score ranked
Tropimech mixed with ash and stored in ZECC (TZA)	2	3
Pectomech mixed with ash and stored in ZECC (PZA)	1	3
UC82 mixed with ash and stored in ZECC (UZA)	1	2
Local mixed with ash and stored in ZECC (LZA	1	3
Lemongrass ash (LG)	1	-
Tropimech without ash and stored in ZECC (TZW)	1	4
Pectomech without ash and stored in ZECC (PZW)	1	2
UC82 without ash and stored in ZECC (UZW)	1	2
Local without ash and stored in ZECC (LZW)	1	3
Neem oil (NO)	2	

*1. None, no symptoms/any physical injuries, 2. Slight, minor symptoms of physical injury, which would not affect retail price, 3. Moderate symptoms of physical injury are evident; the retail price may be affected, 4. Severe, serious physical injuries, not marketable without a substantial price reduction, 5. Extreme, unusable; no market value

There were variations in decay for all treatments during both rounds in both places (table 7), which complicates generating preliminary conclusions. A preliminary conclusion is that the initial quality of the fruits seems to play an important role.

Table 7. Percentage Weight loss/Percent of Tomatoes at Doku

Treatments	Total weight loss (%)		Total % Percent decay	
	First Trial	Second Trial	First Trial	Second Trial
TZA	26.05	6.70	22.08	59.92
PZA	25.28	9.06	15.88	58.28
UZA	30.09	12.92	27.86	66.07
LZA	15.35	7.61	19.58	81.90
TAA	20.68	22.61	60.00	36.17
PAA	16.34	10.37	80.00	90.00
UAA	16.94	11.46	70.00	63.08
LAA	24.12	15.65	55.45	55.00
TZW	13.63	8.38	26.67	40.74
PZW	13.91	16.13	18.61	53.08
UZW	17.21	6.99	41.82	44.22
LZW	20.11	7.07	22.78	64.09
TAW	17.66	7.24	54.49	89.29
PAW	18.07	17.52	40.83	59.92
UAW	10.01	10.77	57.50	58.28
LAW	10.72	9.17	78.18	66.07

*Tropimech in ZECC with Ash = TZA, Pectomech in ZECC with Ash = PZA, UC8213 in ZECC with Ash = UZA, Local in ZECC with Ash = LZA, Tropimech at ambient with Ash = TAA, Pectomech at ambient with Ash = PAA, UC8213 at ambient with Ash = UAA, Local at ambient with Ash = LAA, Tropimech in ZECC without Ash = TZW, Pectomech in ZECC without Ash = PZW, UC8213 in ZECC without Ash = UZW, Local in ZECC without Ash = LZW, Tropimech at ambient without Ash = TAW, Pectomech at ambient without Ash = PAW, UC8213 at ambient without Ash = UAW, Local at ambient without Ash = LAW

This sub-activity will be carried forward to next year so that firmer conclusions and recommendations can be made.

Figure 6. Post-harvest trials on the zero energy cooling chambers along with farmers training in Ghana, 2021. Photo Credit: Jean Baptiste Tignegre/World Vegetable Center.

Activity 1.1.2: *Test and disseminate a combination of improved breeds, housing, feeding, health, and breeding practices to intensify rearing of livestock (sheep, goats, pigs, and poultry) for meat, eggs, and milk production*

Sub-activity GH1121-20: Efficient feed utilization through improved feed troughs (Lead Institution: ILRI)

The partner finished this sub-activity and published a journal paper on the use of the improved troughs, which was published in July in Tropical Animal Health and Production and can be accessed here: https://link.springer.com/article/10.1007/s11250-021-02847-4

The Publication was building on previous efforts that were summarized in a Technology Brief on Feed and Health package for improved small ruminant production: https://hdl.handle.net/10568/112912

Sub-activity GH1123-20: Assess the effect of feeding maize leaf stripping on digestibility and growth performance of small ruminants and interactions of the technology with child labor (more specifically herding of small ruminants) and school attendance of boys and girls

Three separate experiments were conducted at Duko, Tibali, Cheyohi no. 2, and Tingoli in the northern region to determine the effect of maize leaf strippings on 1) fodder yield, 2) growth performance and digestibility of sheep, and 3) carcass and meat/eating quality of sheep supplemented with leaf strippings in the dry season. The treatments consisted of a Control and Leaf stripping. An area of 4×4 m within each farmer's maize farm was randomly selected and used to determine fodder yield by stripping the leaves below the cob. A total of 16 farmers, each with a minimum of 5 sheep, were used in a growth performance experiment. In addition, the study looked at how leaf stripping affected livestock feeding and herding roles and the school attendance of boys and girls.

Both males and females spent similar time (185 vs. 188 sec.; P= 0.951) stripping a 4 m2 field. The fodder yield per natural pasture (889.6 kg DM/ha) and maize field (1,175.7 kg DM/ha) did not differ significantly. School attendance was generally higher but similar for girls in the Leaf

stripping and Control households (76.3% vs. 71.0%). Still, the attendance rate was lower for boys (58.7%) than girls (71.0%) in Control households. The results suggest that leaf stripping has a bigger impact on the school attendance of boys than girls. Most girls usually go to southern Ghana after completion of their Junior High School education. The involvement of the boy-child in livestock production has some benefits and should not be discouraged entirely. Most boys (26.7%) involved in livestock production gained useful life skills such as responsible attitudes and the ability to handle mistakes (Abdul-Rahman et al., 2021).

Data on growth performance has been collected for 11 weeks, and the results indicate a positive effect of supplementing maize leaf strippings (see table 8).

Table 8. Effect of supplementing maize leaf stripping on growth performance, carcass and sensory characteristics of sheep grazing on natural pasture

	Control	Maize leaf stripping	SEM	P-value
DM intake (g/d)	-	1.64±0.003	-	-
Initial weight (kg)	14.75	14.48	0.404	0.6375
Final weight (kg)	16.35	18.21	0.108	<.0001
Weight gain (kg)	1.74	3.60	0.108	<.0001
ADG (g/d)	22.92	47.41	1.426	<.0001

These improvements did, however, not result in improvements in the eating quality of the meat as there was no significant difference (P≥0.075) between the meat of sheep fed maize leaf strippings and those grazing on natural pasture (table 9). The higher drip losses (2.5 vs. 1.2%; P= 0.034) in the meat of sheep fed the maize leaf strippings and the weight of the skin (1.2 vs. 1.4 kg; P=0.014) will have economic implications on the profit margins of the local butchers. The fat content of the diet greatly influences changes in the eating quality of meat; hence differences in the eating quality of the meat were not expected.

Table 9. Effect of supplementing maize leaf stripping on carcass and sensory characteristics of sheep grazing on natural pasture

Carcass characteristics	Control	Maize leaf stripping	SEM	P-value
Slaughter weight	13.64	17.99	1.065	0.045
Carcass weight	5.77	7.69	0.470	0.045
Dressing percentage	42.37	42.73	0.614	0.702
Chuck	0.55	0.72	0.049	0.065
Drip loss	1.21	2.55	0.300	0.034
Legs	0.40	0.47	0.021	0.084
Liver	0.28	0.36	0.026	0.094
Loin	0.59	0.83	0.053	0.032
Neck	0.53	0.66	0.036	0.058
Head	1.14	1.39	0.079	0.092
Lung	0.21	0.27	0.016	0.053
Empty GIT	1.14	1.61	0.061	0.005
Heart	0.07	0.09	0.007	0.101
Spleen	0.04	0.05	0.005	0.251
Kidney	0.05	0.08	0.009	0.067
Testis	0.25	0.30	0.015	0.091

Skin	1.17	1.43	0.044	0.014
Tail	0.06	0.32	0.170	0.340
Eating/sensory quality				
Flavor	6.46	6.35	0.216	0.706
Colour	5.88	5.37	0.204	0.075
Aroma	6.73	6.90	0.204	0.550
Tenderness	6.33	6.25	0.188	0.773
Juiciness	6.06	5.69	0.230	0.263
Texture	6.23	6.15	0.224	0.809
Overall likings	7.23	7.42	0.197	0.492

Most control farmers wanted to switch groups and start feeding maize leaf strippings, indicating they considered the new technology advantageous. The digestibility and economic studies have not been finalized yet and will be reported in the next period.

Figure 7. Harvesting and weighing of maize leaves. Photo Credit: Addah Wesseh/UDS.

Activity 1.1.3: *Test and disseminate integrated crop-livestock-soil and agroforestry systems to increase and sustain productivity and reduce risk.*

Sub-activity: MA1131-20: Risk management and informed decision making towards sustainable intensification of crop-livestock systems (Lead Institution: WUR).

This study aimed to assess the state of representative farming systems in southern Mali in the near-term future (2027) based on biophysical and socio-economic trends in sub-Saharan Africa, thereby identifying promising pathways that enable SI. Accordingly, a model was developed to assess SI in the baseline situation and six subsequent scenarios, based on incremental policy intervention and agricultural intensification strategies, for 411 smallholder farms in southern Mali's 'old cotton basin.' The model checked for different SI indicators from four domains of sustainability. Three promising pathways were identified under the assumption that SI's main objective is intensification in sub-Saharan Africa. Firstly, the successful promotion of contraceptives combined with job opportunities outside of agriculture reduced the pressure put by the rapid population growth on smallholder systems. Secondly, closing the yield gap up to 85 % of the water-limited yield through different means distinctly intensified the system. However, trade-offs with the environmental domain were identified. Lastly, the implementation of inventory credits for cereals increased the profitability but, more importantly, reduced farmers' dependency on the cotton sector. Eventually, the research underlines that only a combination of multiple potential pathways can truly enable SI. The project team develops further knowledge products from this work in the form of technology label briefs.

Output 1.2: *Integrated management practices and innovations to improve and sustain productivity and ecosystems services of the soil, land, water, and vegetation resources are developed and disseminated with farmers and development partners in the intervention communities*

Activity 1.2.1: *Test and disseminate land, soil, and integrated land–soil technologies and practices to improve and sustain productivity and ecosystems services at the farm and landscape/watershed levels*

Sub-activity GH1211-20: Assessing buffer and adaptive capacity to harness the resilience of different farm types (Lead Institution: WUR).

In this sub-activity, a draft journal article entitled 'Preparing for, coping with and bouncing back aftershocks. A nuanced resilience assessment for smallholder farms and farmers in Northern Ghana was submitted to a journal in October 2020 but was rejected. The project team promised to revise and resubmit the Journal paper.

Sub-activity MA1211-20: Determination of cropping management factors using empirical relations, GIS and Remote Sensing tools in two agro-ecologies of Mali (Lead Institution: AMEDD)

This sub-activity is in its second year of being conducted in Mali. The objectives of this sub-activity are:

i. Determination of cropping management factors using empirical relations, GIS, and Remote Sensing tools in two agro-ecologies of Mali.
ii. Assess the impact of soil erosion on landscape soils productivity.
iii. Evaluate variations of plant-available nutrients, such as carbon, nitrogen, phosphorous, and potassium in different agro-ecologies under different land-use systems.
iv. Identify areas affected by natural and anthropogenic changes.

v. Provide appropriate guidance and recommendation on environmental protection to help increase crop productivity and reduce soil degradation.

Table 10. Farmers participating in the Focus Group Discussions (FGD) at different villages.

Villages	Male	Female
Dieba	9	3
Sibirila	10	3
Madina	10	3
Flola	7	6
N'golonianasso	7	4
Nampossela	11	4
M'pessoba	8	3
Sirakele	8	5
Zanzoni	9	7
Total	**79**	**38**

A survey involving 117 participants (Table 10) was conducted to investigate farmers' perceptions of the influence of soil water erosion on smallholder farm income and the impact of erosion on aggravating poverty and outward migration. The data was collected in February 2021 for ten days in the nine Africa RISING intervention villages. A strict follow-up of the covid-19 protocol was carried out while conducting the survey.

Data analysis revealed that soil water erosion is a common phenomenon, causing problems in the local farming system by reducing agricultural productivity and land degradation. Causes of soil water erosion were discussed in the Focus Group Discussion (FGD), and participants highlighted that deforestation is one of the major contributors to the high rate of erosion. The majority of participants (80%) considered soil erosion as severe, and it is among the factors that decrease productivity and the income of the rural household.

The most visible effect of soil erosion in the studied villages, according to participants of the FGD, is in the environmental domain, with a percentage, decreased trees cover over time, and a high rate of soil nutrients washed from most farmlands, the livelihood of the rural communities is at stake.

Locally adapted technologies and practices by farmers to curb erosion include stone lines, tree plantation, and contour bunding. These techniques are effective for reducing soil erosion, and farmers are willing to implement the practices. Though most farmers witnessed, implementing soil and water conservation practices consumes much of their time and labor. A draft report on 'Assessing cropping management factors using empirical relations, GIS and Remote Sensing tools in two agro-ecologies of Mali is being prepared by the team for subsequent review for possible uploading on the CG Space.

Sub-activity GH1212-20: Assess the impact of soil and water conservation interventions in maize - cowpea living mulch system (Lead Institution: KNUST)

This sub-activity has been completed and was on-going for the last three years. The main objective was to monitor soil moisture retention, depletion cycles, and nutrient fluxes within cropping systems in selected soil and water conservation practices and crop growth trends. The study was conducted in four (4) communities: Tibali and Duko in the Savelugu District, Tingoli in the Tolon District, and Cheyohi in the Kumbungu District Northern Region of Ghana. A Journal article was submitted to Field Crops Research in March 2021. Extension material as a Soil and Water Conservation Guidebook was developed and final design before broader dissemination.

Sub-activity MA1212-20: Improving crop-livestock productivity and household income through the use of contour bunding and agroforestry options (Lead institution: IER-Mali)

This sub-activity is conducted in Mali to improve crop and livestock productivity and household income with contour bunding technology (CBT) and agroforestry options. The major objectives are to assess a) the role of CBT towards increasing households' resilience against droughts, b) evaluate crops and fodder plants growth and yields under CBT, evaluate the effect of micro-dosing and intercropping on yields, d) develop a business model on nurseries that engage the youth and women farmers.

Effect of CB technology on fodder ligneous growth and yield: In the rainy season of 2020, CBT significantly ($p<0.05$) increased the growth and development of fodder ligneous of *Gliricidia sepium* and Leucaena leucocephala planted in 2019. At the end of the rainy season, the taller Leucaena of 2.6 m on average was measured in CB plots and 1.8 m in the control (Figure 8).

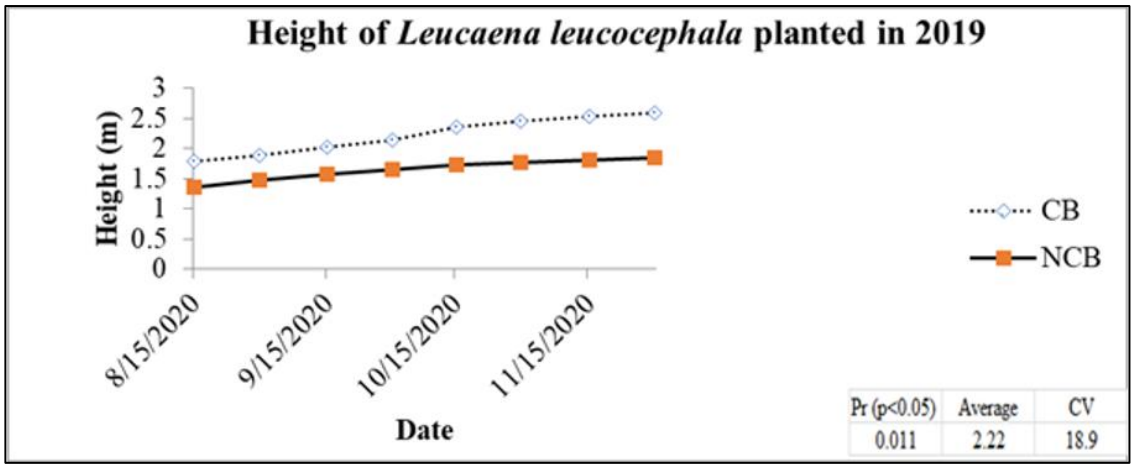


Figure 8. Effect of CB on the height of Leucaena leucocephala, planted in 2019.

A larger basal diameter of 28.6 mm of Leucaena was observed in CB plots and 21.6 mm in NCB plots (Figure 9). A height of 1.3 m and a diameter of 16.4 mm were observed in CB plots and 11.3 mm in farmer's practice plots. Wider crowns of 0.93 m radius were found in CB plots compared to 0.53 m in the control. Analyzed results showed that fresh biomass yields of fodder trees were significantly ($p<0.05$) higher in CB plots than in NCB plots. Average fresh biomass yields of G. Sepium and L. Leucocephala were 26.56 kg/plant and 17.1 kg/plant in CB plots and 17.1 kg/plant and 12.44 kg/plant in the control, respectively.

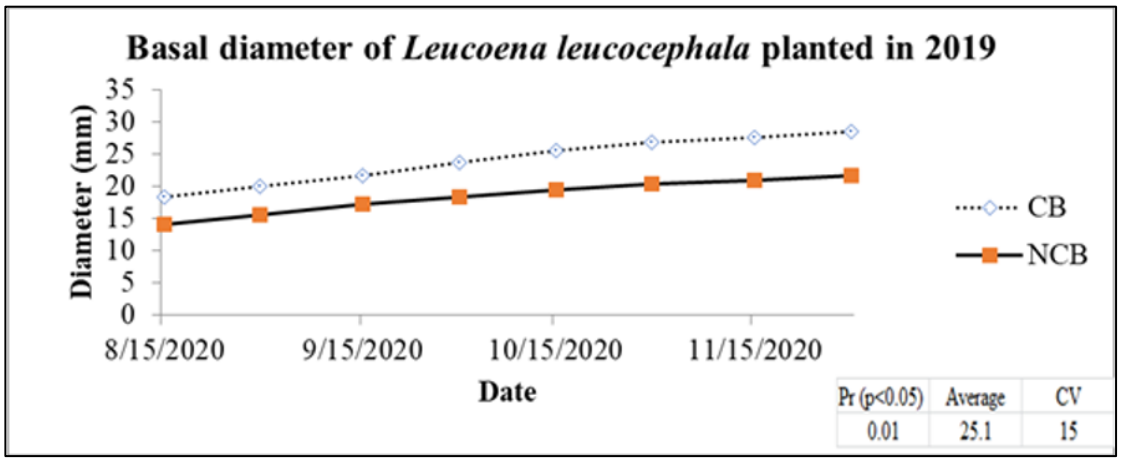


Figure 9. Effect of CB on the basal diameter of Leucaena leucocephala, planted in 2019.

- Effect of intercropping and CB technology on soybean growth and yields
- Grain and straw yields of soybean significantly ($p<0.05$) increased using intercropping and CB technology.

Table 11. Effect of intercropping and CBT on soybean grain and straw yields.

Grain yield of soybean		**Straw yield of soybean**
Sole soybean	1,475	2,605
Soybean-sorghum	2,058	3,102
F.pr (0.05)	0.031	0.014
Average	1,766	2,854
Soil conservation		
CB	2,1345	3,230
NCB	1,399	2,477
F.pr (0.05)	0.008	<0.01
Average	1,766	2,854
CV %	35.01	16

Grain and straw yields of soybean significantly ($p<0.05$) increased using intercropping and CB technology. Grain and straw yields were 1,475 kg/ha and 2,605 kg/ha in sole soybean plots and 2,058 kg/ha and 3,102 kg ha in intercropped soybean-sorghum plots respectively. Soybean gave 2,134 kg/ha grain yield and 3,230 kg/ha straw yield in CB plots and 1,399 kg/ha and 2,477 kg/ha grain and straw yields respectively in NCB plots, respectively (Table 11). Intercropping significantly ($p<0.05$) increased soybean growth. Soybean growth significantly ($p<0.001$) increased by CB technology. Soybean height and diameter were 0.74 m and 11.55 mm in sole

soybean plots and 0.9 m and 13.7 mm in soybean-sorghum plots. Height and diameter were 0.95 m and 14.17 mm in CB plots and 0.69 m and 11.09 mm in the control, respectively (Table 12).

Effect of CB technology on growth, yields, and economic profitability of crops (sorghum, millet, and maize): Contour bunding significantly ($p<0.05$) increased crops growth and yields. The difference was highly significant ($p<0.01$) with the millet crop. Grain yields of sorghum, millet, and maize were 2,030 kg/ha, 2,367 kg/ha, and 3,431 kg ha in CB plots against 1,375 kg/ha, 1,546 kg/ha and 2,479 kg ha, respectively in NCB plots.

Table 12. Effect of CBT on grain and straw yields

Grain yield of crops (kg/ha)			
	Sorghum	**Millet**	**Maize**
Soil conservation			
CB	2030	2367	3431
NCB	1375	1546	2479
F.pr (0.05)	0,004	<,001	0,014
Average	1702	1956	2955
CV %	32,6	17,3	18,8
Straw yield of crops (kg/ha)			
	Sorghum	**Millet**	**Maize**
Soil conservation			
CB	7863	7321	6153
NCB	5598	5046	4340
F.pr (0.05)	0,046	<,001	0,007
Average	6731	6183	5247
CV %	42,4	26,3	17,6

Straw yields of 7,863 kg/ha, 5,046 kg/ha, and 6,153 kg ha were observed in CB plots compared to 5,598 kg/ha, 5,046 kg/ha, and 4,340 kg ha in the control in sorghum, millet, and maize, respectively. The VCR of CB was 2.1, 3.9, and 1.8 for sorghum, millet, and maize, respectively.

This sub-activity will be carried forward since additional data is required to reinforce accuracy on micro-dosing and its impact on soybean intercropped with sorghum under contour bunding. Also, next year attention will be paid to scaling up the technology.

Activity 1.2.2: *Test and promote water management technologies and practices to increase water productivity in the small-scale crop–livestock farming systems under rainfed and irrigated conditions*

Sub-activity GH1221-20: Evaluate the technical and agronomic performance of Bhungroo and solar-energy drip irrigation system in the Upper East Region of Ghana (Lead Institution: IWMI)

The sub-activity (GH122-19) was implemented during the 2019/2020 dry season with the primary objective of evaluating the technical and agronomic performance of solar-powered drip irrigation systems in two communities of Sepaat and Gorogo. Some of the significant activities included field experiments that were executed, and data collection is ongoing. The Project team

is building on past work (Mante, Y, F. Salifu, M. Mul, D. Kadyampakeni, M. Magombeyi and Z. Adimassu. 2018. Characterization of sites for aquifer storage and recovery system in Northern Ghana. Secure Water: Bhungroo Site Characterization- Final Report, IWMI) to provide a final report on this activity.

Sub-activity MA1221-20: Evaluate improved irrigation technologies for efficient and sustainable agricultural water management in rural Mali

The main objective was to evaluate existing initiatives and constraints in using efficient and sustainable water management practices using solar energy power pumps and improved irrigation technologies. It combines GIS and remote sensing technologies with climate information (e.g., solar radiation, hours of sunshine, etc.) to characterize and define suitable zones to implement solar-based energy pumps for irrigation in Koutiala and Bougouni. Figures 10a and 10b reflect the suitability maps for Bougouni and Koutiala, respectively.

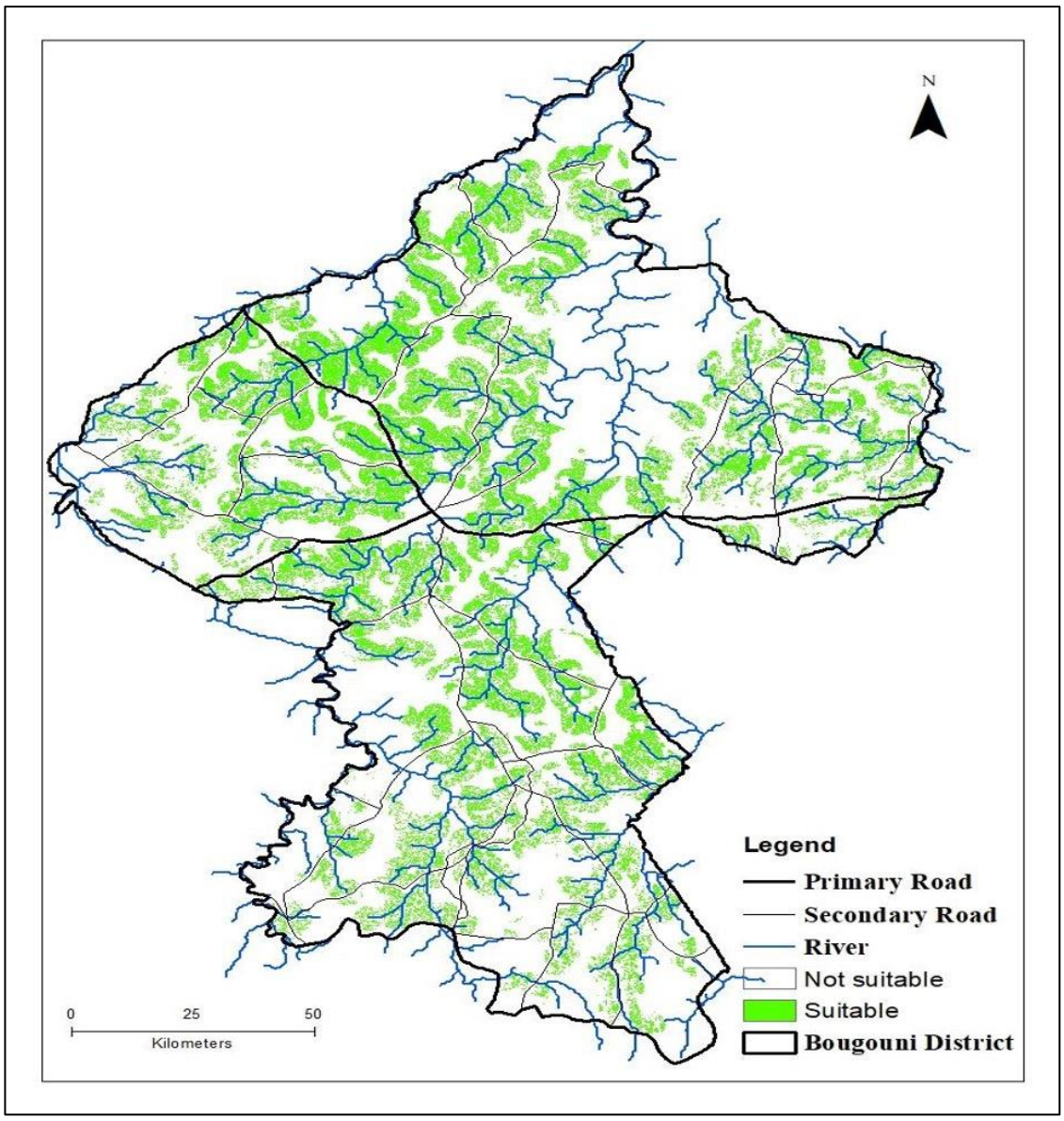


Figure 10a. Solar-powered irrigation suitability map Bougouni District.

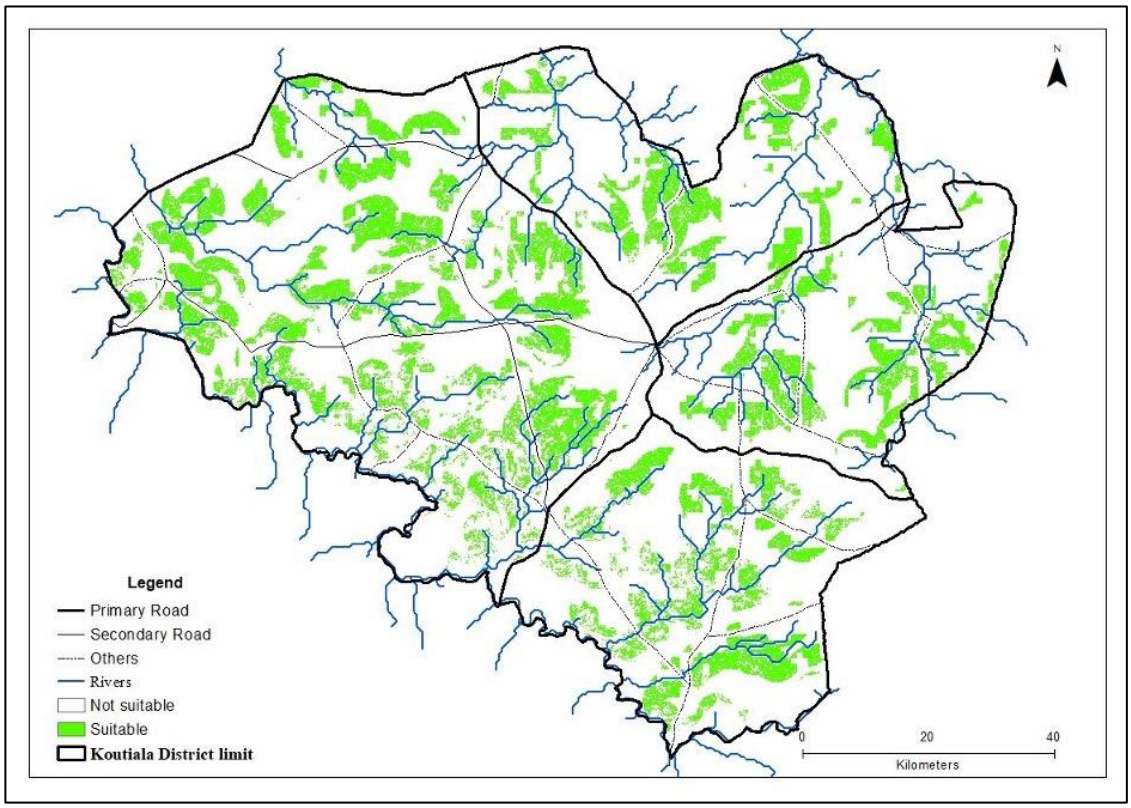


Figure10b. Solar-powered irrigation suitability map Koutiala District.

Suitable areas for solar PV implementation in the districts of Bougouni and Koutiala were identified using MCDA techniques in a Geographical Information System, which allows the solution of complex problems and facilitates decision-making. The analysis showed considerable potential for solar PV-based irrigation in the two districts. This suitability mapping can provide the necessary input to support planning and sustainable implementation of solar-based irrigation, which offers various social and economic benefits. These results should be integrated into plans for overall sustainable irrigation development, and more specifically, to evaluate possible investments in solar pump business models for irrigation. A report titled 'Irrigation technologies for efficient and sustainable agricultural water management in rural Mali focusing on land and soil characterization of potential agricultural investment zones in Bougouni and Koutiala' has been finished and can be consulted through the below link.
https://cgspace.cgiar.org/bitstream/handle/10568/113774/water%20management%20in%20rural%20Mali%20report.pdf?sequence=1&isAllowed=y
This sub-activity will be carried forward to the 2021-2022 season, emphasizing the multi-criterial-decision-making (MCDM) tool developed as a planning and management solution to assess the potential of agricultural water management investments.

Sub-activity GH1411-20: Produce regionally relevant extrapolation domain maps for validated integrated technology packages

Mapping the dates and the trends of the onset and cessation of rainfall over space will ensure timely delivery of agro-advisories on the cropping calendar activities such as plowing, sowing, fertilizer application, and harvesting. The results revealed that the region's rainfall indices have substantial latitudinal variability with the rainfall onsets recorded at the north of 10o N latitude between 15th April – 25th May, while at the south of 10^{o} N latitude occurred between 21st March – 15th April. We observed that daily satellite rainfall (CHIRPS-v2) is biased towards capturing early onsets and late cessations. Therefore, the study recommends bias correction of daily CHIRPS-v2 data for reliable agro-advisories targeting climate smart-agricultural technologies. The study considered farmers' perceptions of rain season timing changes, considering that traditional knowledge is an essential trigger of climate adaptation. Farmer perceptions on changing rainfall patterns are a vital determinant of annual cropping decisions. If farmers' perceptions agree with the trends recorded by the observation network, it means more awareness of prevalent trends and a higher likelihood of applying adaptive measures. Farmer's perceptions of trends of onset and cessation of rains showed considerable variation from the gauge data over time and space.

Lessons learned

Approximately 29% of farmers rely on meteorological agencies' data to forecast the rainfall season's start, while the remainder depends on traditional knowledge. Adaptation measures were not always consistent with the rainfall seasonality. CHIRPS-v2 has inherent systematic biases that could come from low density and decreasing gauge observations over time in Ghana, leading to insufficient representation of rainfall indices. Integrating scientific observations and local knowledge on rainfall seasonality would improve advisories and ultimately generate robust adaptation to climate change and variability. This sub-activity will be carried forward to the next year, and two publications are expected. One of the publications has been accepted in the Journal entitled “Atmosphere.” The Journal article title is *Trends of Rainfall Onset, Cessation, and Length of Growing Season in Northern Ghana: Comparing the Rain Gauge, Satellite, and Farmer’s Perceptions.* Authors: Winifred Ayinpogbilla Atiah, Francis K. Muthoni, Kotu Bekele, Fred Kizito, Leonard K. Amekudzi.

Outcome 2: More farmers and farm families are adopting technologies and practices to improve nutrition, food and feed safety, postharvest handling, and value addition

Output 2.1: *Improved technologies, innovations, practices, and habits to increase production and consumption of safe diverse and more nutritious food for farm families, especially by women and children, developed and disseminated in partnership with research and development partners*

Activity 2.1.2: *Increase the capacity of farm families, especially women, to produce and consume diverse and more nutritious food*

Sub-activity GH2121-20: Container gardening training combined with nutrition education for improved vegetable consumption (Lead institution: UDS-SH)

This study builds on the GH2121-19 sub-activity that investigated the impact of nutrition education through radio broadcastings explaining the nutritional value and preparation of vegetables. The research finding was that the availability and/or production of vitamin-rich fruits and vegetables is crucial for increasing consumption. Home gardening would be a good alternative, but some households lack access to land. Therefore, this study evaluates whether training in container gardening combined with nutrition education impacts caretakers' nutrition knowledge and attitudes and whether it positively impacts the intake of vitamin-rich fruits and vegetables of children aged between 6-36 months. Four hundred twenty-two households were selected in 5 districts in Northern Ghana, of which 110 were trained in container gardening combined with nutrition education, 122 were trained in container/ home gardening alone, and 190 formed the control group. In the study sample, the consistent predictors of adequate fruit and vegetable consumption were a) ownership of a container/home garden combined with nutrition education, b) being resident in the Upper East region, c) older children, d) high father's involvement. The multivariable logistic regression analysis indicates that the household members of the group trained in vegetable container gardening plus nutrition education were 3.53 times more likely to consume vitamin-rich fruits and vegetables. The older children, aged between 24-36 months, were 7.12 times more likely to consume vitamin-rich fruits and vegetables than the younger ones. Residents from the Upper East region were 5.7 times more likely to consume vitamin-rich fruits and vegetables than residents from the Upper West. This is not strange since these are more abundant and easier to access in the Upper East than in the Upper West. Households with fathers highly involved in childcare and feeding activities were 6.1 more likely to eat vitamin-rich fruits and vegetables (see sub-activity GH2122-20). This study will be finalized next year and present recommendations for scalable interventions addressing the inadequate intake of micronutrients in Ghana's Upper West and Upper East regions.

Sub-activity GH2122-20: Engaging men to increase support for optimal child feeding practices using the care-group approach/model

This sub-activity closely relates to GH2121-20. Most community programs addressing to improve the well-being of women and children target mothers and their children with little attention to the fathers. This created a situation where the mothers understand nutritional issues better than fathers. In practice, men play a significant role in making household decisions. This sub-activity intends a) to find out whether men are willing to be engaged in discussing and promoting child feeding in Northern Ghana, b) the influence and effect of fathers' participation

in nutrition education sessions on child feeding practices and the nutritional status of their children under three years. The study selected 420 fathers with children between 6-36 months over the 25 Africa RISING communities. The knowledge and attitudes of the fathers concerning childcare and feeding were measured during interviews. It results that the fathers' involvement in childcare and feeding were positively influenced by the key factors: father's nutrition-related attitudes (positive related attitudes: 2.87 times likely more involved), the district of residence (Africa RISING intervention area 1.68 times more), and the socio-economic status as measured by the wealth index (1.85 times more). These preliminary findings suggest that men can act as agents of positive change in supporting women to feed their families adequately. This sub-activity will be finalized next year and will present the final figures and recommendations on engaging men in interventions targeting improved child and household nutrition.

Output 2.2: *Postharvest technologies and practices to provide options for the food, and feed sectors are tested and disseminated to farmers, through researchers, extension staff, and development partners*

Activity 2.2.1: *Introduce, evaluate, adapt, and disseminate existing postharvest technologies and practices*

Sub-activity GH2211-20: Evaluate the threshing efficiency of different maize shellers with regards to grain quality characteristics as influenced by different varieties and harvest timing (Lead institution: SARI)

This sub-activity is complementary to ongoing work conducted by IITA in Sub-activity 2212 entitled "*Monitoring group dynamics among users of small-scale maize shelling machines in Northern Ghana*." This sub-activity examines the emerging role of maize threshing machines in northern Ghana and identifies options to address their accessibility, adoption, and operational efficiency. The study was conducted in four districts in the Northern Region of Ghana. The effect of threshing techniques on efficiency characteristics (damaged grain, whole grain, and overall physical purity) was assessed. This study suggests the necessity to upgrade postharvest operations to accommodate emerging developments and dynamics of agricultural intensification where the use of human labor has become costly and less efficient. This study examined (1) the emerging role of mechanized harvesting and threshing operations in northern Ghana and options to address their availability, cost, adoption, and operational efficiencies, and (2) threshing performance characteristics of different maize threshers and socio-economic benefits to farmers. The shelling study has been extended to soybeans and groundnuts.

Soybean shelling operations

Shelling Manual harvesting and threshing of soybean pose a major limitation to large-scale production and mainly burdens women. From the key informant interviews, the main challenges were lack of threshing machines, cost of threshing services, and lack of financial capacity to own a machine. The cost of acquiring threshing machines appears to be high for smallholder farmers. A few well-endowed farmers offered threshing services at a fee. However, the presence of local fabricators in Ghana could reduce the cost of such machines if the government can support the artisans. Time spent in soybean harvesting operations (harvesting, conveying, and threshing) was estimated at 14 to18 man-days/ha (112 to 144 hours/ ha). Table 13 describes grain moisture (7.2%), 100 seed weight (11.2g), physical purity (94.6%), and threshing losses (4.2%) in soybean. The major quality defects requiring attention were a high proportion of shriveled grain

due to immaturity, broken grains, and high inert materials due to late planting or inadequate nutrition.

Table 13. Grain moisture content, physical purity, and threshing losses in soybean

Description	Grain Moisture content (%)	100 Seed weight	Grain physical purity (%)	Estimated threshing losses (%) [CI at 95%]
Northern	7.3	12	94.4	4.6[3.1-6.1]
Upper East	6.9	10.5	95.1	4.0[2.5-5.5]
Afayak	7.1	11.5	94.8	1.9[0.23-3.6]
Favor	6.9	11.2	94.3	4.5[2.1-6.9]
Jenguma	7.6	11.3	95.8	3.6[1.5-5.7]
Songda	7.3	11.3	95.0	4.6[1.1-5.9]
Suong-pungun	7.3	11.2	93.9	4.4[2.1-7.9]
Unknown	7.2	10.8	94.5	1.5[1.3-7.9]
Grand mean	7.2	11.2	94.6	4.3
CV (%)	5.5	6.3	12	72.2

Groundnut shelling operations

Across the communities, manual harvesting, stripping, drying, and shelling were the dominant practices. The drudgery postharvest operations were harvesting (55.5%), stripping (20%), and shelling (24.4%). Time spent in groundnut harvesting operations (harvesting, stripping, and drying) was estimated at 30 to 35 man-days/ha (240 to 280 hours/ ha). The grain moisture content of on-farm samples was 7 to 9%, which was within safe limits (table 14). The use of shelling machines recorded shelling losses of 9 to 19.7% and physical purity of 80 to 89% compared to manual shelling (93 to 98%). Grain physical purity has implications on price, aflatoxins, and subsequent pest infestation. Although the traders carried out sorting and grading just after shelling, the downgrades shriveled, split, and broken nuts) were smuggled into the food chain. From the SWOT analysis, five weaknesses requiring attention were drudgery at harvesting, stripping, and shelling; drying on bare ground; scarcity of shelling machines; risk of aflatoxins; and access to postharvest infrastructure (drying platforms, drying cocoons, tarpaulins, moisture meters, etc.). The actors should continue to map opportunities to improve the efficiency of harvesting, stripping, drying, and shelling operations and provide training on good postharvest management.

Table 14. Grain moisture content, physical purity, and threshing losses in groundnut

District	% grain moisture	% broken grain	% Physical quality losses (Inert, broken, shriveled, moldy, small size)	% Grain physical purity
Kasena NE Mun.	7.6	0.8	9.5	89.4
Binduri	7.4	4.3	11.1	88.4
Savelegu	7.4	3.2	15.8	82.0
Karaga	7.1	2.2	17.1	82.2
Grand mean	7.4	2.8	13.0	85.5
Sig. level	Ns	0.01	0.01	0.01
$LDS_{(P<0.05)}$	0.7	1.0	4.2	4.1
CV (%)	13	107	44	6

Figure 11. Maize and groundnut shelling. Photo Credit: Wilhelmina Ofori-Duah/IITA.

Shelling was made more accessible by introducing semi-mechanized diesel-powered maize shelling machines (R170A Max. Engine power: 4.95Ps, 12hr rated power 4.5Ps, declared speed: 2,600r/min). Madam Clara Joseph is a smallholder maize farmer, producing about 1 acre of yellow maize (Abontem). Last year, we (3 family members) spent one-day harvesting and conveying to shade. We (3 members) spent two days to dehusk and ten days to shell, spent one day to winnow the maize (6 bags). But this year, the shelling and winnowing were done in less than 1 hour compared to 11 days last year. The grain is clean, and secondly, we can use the cobs as fuelwood. The shelled grain is very clean with little breakage. The cost of shelling (GHC3/ bag or one bowl/bag) is 'just peanut' compared to the labor involved in manual shelling. I can utilize the rest of my time in other economic activities and spend quality time in the night with my children and family.

Six leaflets are being revised and redesigned:

i. Modified harvest maturity scale to guide maize harvesting operations
ii. Modified harvest maturity scale to guide groundnut harvesting operations
iii. Modified harvest maturity scale to guide soybean harvesting operations
iv. Maize: Best harvest and post-harvest practices
v. Maize: Benefits of using shelling machines
vi. Soybean: Best harvest and postharvest practices

vii. Groundnut: Best harvest and postharvest practices

This sub-activity will be carried forward and will put more focus on groundnut post-harvest operations. Different approaches involving field measurements of shelling losses, focus group discussions, farmer field schools, technical leaflets, and key informant interviews are employed. All activities are concentrated in 3 districts, namely Bongo and Kassena Nankana East Municipal (KNEM) in the Upper East Region and Savelugu District in the Northern Region.

During the Reporting Period, the SARI Postharvest team supported the training of several Africa RISING farmers and beyond on postharvest techniques table 15). The training was a ToT (training of trainees).

Table 15. Total number of participants for the training

Date	Region	Description of participants	Number of participants		Total
			Male	Female	
Oct. 6-7, 2021	UWR, Wa Tiergberi Catholic Centre	Trainees	9		9
		DEGAS	3		3
		IITA-AR	3	1	4
		CSIR-SARI	2	-	2
			Total		**18**
Oct.11-12, 2021 Total	NR, Tamale, Arewa Sunshine Hotel	Trainees	7	-	7
		DEGAS	3		3
		IITA-AR	3	1	4
		CSIR-SARI	2	-	2
			Total		**16**

Training contents

- General concepts of postharvest technology, food losses, and food security
- Basic concepts (maturity, harvesting, conveying, drying, storage, packaging, processing) of the postharvest chain
- Harvest and postharvest operations with emphasis on maize
- Methods of Storage (traditional, improved, and advanced with a focus on maize
- Video documentary of best postharvest technologies
- Methods of loss assessment
- Sampling and sampling methods
- Calculating postharvest losses
- Field visit and practical session
- An essential skill in monitoring and evaluation
- Evaluation session
- Closing session

Figure 12. Participants identify the maturity signs to observe before harvest. Photo credit: Wilhelmina Ofori-Duah/IITA.

Further details on the training are available in the TRAINING OF TRAINEES REPORT HERE

Sub-activity MA2211-20: Reduce vegetable postharvest losses through the dissemination of Zero Energy Cool Chamber (ZECC) and processing of vegetables and capacity building in the dry season in Bougouni and Koutiala

The objective of this activity was to evaluate the performance of different storage methods on the shelf-life and quality of tomato varieties and to train producers on the use of these technologies. It is comparable with sub-activity GH1116-20.

Two Zero Energy Cooling Chambers (ZECC) were installed in each technology park (Bougouni and Koutiala) and used to set up the tomato storage experiments. The ZECC installation activities witnessed the active participation of the project beneficiaries who were eager to learn how to install the technology and how it works. Two rounds of storage experiments were conducted in each technology park. In the Bougouni technologies park, the first round of storage experiments was conducted between 04 and 13 March 2021, and the second round of storage experiments was conducted between 14 and 23 March 2021. Storage experiments in the Koutiala technologies park were conducted on 06 – 15 April and 16 – 25 April 2021. In each technology park, light-red maturity stage fruits (stage 5) of the tomato varieties Bebiyereye, Keneya, and UC82 were subjected to four storage methods (treatments): fruits storage in ZECC (T1), fruits mixed with ash (1:1 w/w), and stored in ZECC (T2), fruits mixed with ash and stored at ambient conditions (T3) and fruits stored at ambient conditions (T4). Three data loggers (one in each ZECC and one for the ambient storage condition) were placed to record Temperature and Relative humidity conditions during storage. Forty (40) fruits of each variety were placed in a specific plastic crate at the level of each storage method. They monitored at 3, 6, and 9 d for

weight loss, visual quality, and quality attributes (color, firmness, total soluble sugar, titratable acidity, and ascorbic acid). A separate batch of fruits was used for baseline data on quality attributes of the fruits on the day of harvest (day 0). Five fruits were sampled from each experimental unit for the baseline quality analysis and subsequent samplings. Sampled fruits at each sampling day were sent to the WorldVeg Postharvest laboratory in Bamako for quality analysis. Visual quality assessment was performed at each sampling day by 5 to 10 producers using the 5-point rating scale (9 = excellent, 7 = very good, 5 = good, 3 = fair, and 1 = poor) for the overall quality of produce.

Weight loss was significantly affected by the storage method at the different storage durations and increased with the duration for all storage. However, weight loss was lower in the ZECC than in the control treatments (control + ash and control). Also, the combination of the ash with the ZECC did not improve its performance. The reduced weight loss in the ZECC treatment is attributable to the low temperature and high relative humidity occurring within the ZECC, which slow down the physiological processes of the stored fruit. The low temperature and increase in relative humidity in the ZECC are based on the direct evaporative cooling principle when it is watered. The poor performance of the ZEEC with ash could be due to the fact; the ash formed a barrier around the fruits, which did not permit them to sense the evaporative cooling effect in the ZECC adequately. Moreover, the ash likely impacted the fruit's respiration process by concentrating CO_2 and the energy released during the respiration around the fruit since air circulation around the fruit is very limited in the ZECC+Ash treatment. However, research is needed to test options like fine layer application of the ash on the fruit's surface or explore the use of an edible coating like Arabic rubber/gum (produced a lot in Mali) to extend the shelf-life of tomato.

Fruits of the tomato varieties Bebiyereye and Keneya reached their limit of salability at six days of storage in the control treatment and at nine days of storage when stored in the control + ash treatment. With the tomato variety UC82, fruits stored in the control treatments reached their limit of salability at nine days of storage. However, fruits stored in the ZECCs maintained a saleable quality at nine days of storage, with scores ranging between 5.5 – 6.8 compared to 3.1 – 4.4 in the controls. The treatment ZECC without ash showed the best performance in maintaining tomato fruits' quality over the whole period of the experiment. The results of the visual quality assessment suggest that storage of the tomato fruits in the ZECC technology extended the marketable shelf-life of the tomato fruits by three days compared to the fruits storage in ambient conditions. When the two ZECC treatments are considered, the combination of the ZECC with ash negatively affects the visual quality of the tomato fruits. Therefore it is not a good storage option to recommend. In contrast, at the level of the control treatments, fruit storage in ambient conditions with ash was associated with better fruits' quality maintenance than the simple storage in ambient conditions without ash.

Fruit firmness decreased with the storage duration at the level of all storage methods. For Keneya fruits, storage methods did not significantly affect the fruit's firmness. For Bebiyereye fruits, storage methods significantly affected fruit firmness at 3 and 9 days of storage. For UC82 fruits, storage methods significantly affected fruit firmness at 3-day of storage.

For Bebyereye and UC82 fruits, a significant difference between storage treatment was observed only at three days of storage, with the TSS values higher in the control treatments than in the ZECCs. For Keneya fruits, significant differences were observed between treatments

at 3 and 9 days of storage. TSS value in the control treatment was significantly lower than that of the ZECC + ash at 3-day of storage, while at nine days of storage, the TSS value in the control treatment was significantly higher than that of the ZECC. Overall, a clear pattern was not observed for the TSS values concerning the storage methods. TA of Keneya and UC82 fruits was not significantly influenced by the storage methods during the nine days of storage. At the level of Bebiyereye fruits, storage methods influenced TA only at 3-day of storage. TA value was significantly higher in the control treatment than in the other treatments. Ascorbic acid (vitamin C), no significant difference was obtained between storage treatments for the two varieties throughout the experiment. These results could be related to the maturity stage of the fruits used for the experiment. Fruits likely reached their TSS and TA peak at that stage, and therefore storage treatment did not have a significant role in the sugar degradation process. The absence of the effect of the storage methods on the ascorbic acid at the level of the three varieties could be explained by the fact, many factors govern the attribute of ascorbic acid in the fruit, and low temperature and high relative humidity are just two factors among many others. They could not systematically generate a significant change concerning the storage treatments. Picture 14 shows images of the post-harvest trials from tomato fruit harvest from the field to storage in the Zero-Energy Cooling chambers in 2021 in Mali.

Figure 13. Images of the post-harvest trials from tomato fruit harvest in the field to storage in the Zero-energy cooling chambers, Mali 2021. Photo Credits: Jean Baptiste Tignegre/World Vegetable Center.

This sub-activity contains a training component to disseminate knowledge and equipment on best postharvest management practices that reduce product losses during storage through training and exercises. Every training session was limited to 40 participants in compliance with the COVID-19 barriers measures. The training was a mix of theory and practice. Topics covered in postharvest management were maturity indices using color charts, climacteric, and non-climacteric fruits, harvesting techniques, the impact of pre-harvest factors (cultural practices, varieties, etc.), temperature management, and the ZECC. In vegetable processing, theoretical topics covered hygiene, sterilization, pasteurization, drying, juice preparation, vegetable brine, tomato sauce, and concentrate preparation. The practical session in vegetable processing covered hygiene, sterilization and pasteurization, and tomato juice, sauce, and concentrate preparations (Figure 16).

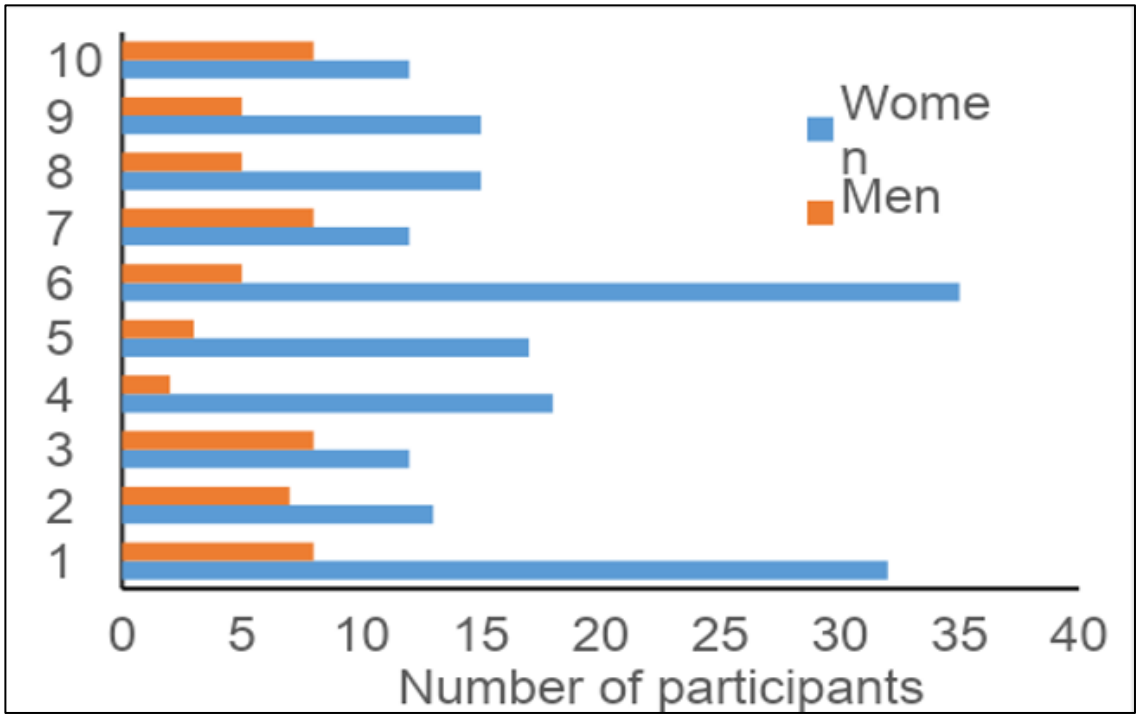


Figure 14. Distribution of trained producers across the various villages associated with the technology parks.

A total of 240 (75% women) producers were trained (120 in Koutiala and 120 in Bougouni) on Postharvest management and processing techniques. The plan was to train the double amount, but COVID-19 made that impossible. Only two ZECC chambers were set up, and it was thought that more people could attend, but the protocols forbid that. Two field days were organized, but also numbers were limited.

This sub-activity will be carried forward to 2021-2022 to get more results, train more farmers, and capture their perceptions of the different post-harvest storage technologies.

Figure 15. Training of women producers on Postharvest management and processing techniques in Mali, 2021. Photo Credits: Jean Baptiste Tignegre, World Vegetable Center.

Sub-activity GH2212: Monitoring group dynamics among users of small-scale maize shelling machines in Northern Ghana

Most smallholder farmers in Northern Ghana do not have access to commercial maize shelling service providers. Consequently, they use the manual method (mainly by using a hand or stick) to shell their maize. The manual method consumes a lot of labor time while it is tiresome. Informal interviews we made with farmers show that it takes several days to shell a bag of maize manually. To solve this problem, the Africa RISING West Africa Project donated diesel-powered small-scale maize shelling machines to 18 farmers groups found in three regions of Ghana (namely, Northern, Upper West, and Upper East regions). A two-year study was initiated around the maize sheller user groups to study the group dynamics, which possibly evolve in the process of using and managing the machines. These included a qualitative study in November 2019 and a two-round survey conducted in March 2020 and March 2021. The qualitative study was conducted in three communities (Duko community in Northern Region, Nyangua community in Upper East Region, and Zanko community in Upper West Region). Farmers were categorized into three (Low Resource Endowed-LRE, Medium Resource Endowed-MRE, and High Resource Endowed-HRE) based on locally validated farm and farmer typology by Michalscheck et al.

(2018[1]). The surveys covered 152 randomly selected farmers who were members of the users' groups. We also conducted discussions with 2-3 committee members of each users' group to get data on group-level activities. Data collection has been completed, and analysis has been started.

The qualitative study results show that all consulted maize sheller group members expressed high satisfaction with the sheller transfer and use. The main drawback of the Africa RISING shellers is that they require manual de-husking, a labor-intensive task that could prevent HRE and LRE farmers from using it. HRE farmers might prefer to hire a larger tractor-operated sheller to save time and labor. LRE farmers with a low yield might prefer to shell by hand to save cash or in-kind payments. The introduction of the maize shellers seems to have strengthened the groups owning it in their trust and social cohesion. In Nyangua, the transfer of the sheller seems to have created some tension between group and non-group members since non-group members felt excluded from the progress that group members were assumed to make with it. The introduction of the maize sheller improved the availability of mechanized shelling services for the whole community, particularly in Nyangua and Zanko, where most farmers shelled manually. In Duko, the introduction of maize shellers made shelling services more affordable, increased the associated community benefit, and reduced drudgery.

The surveys show that about 70% of the sample farmers used the machine managed by their groups. The percentage of farmers using the machine was slightly higher during the first year (72.4%) than during the second year (67.9%). The lower percentage figure associated with the second year could be because of the spoilage of machines managed by some of the groups constraining access to group shelling services. On average, the farmers shelled about 384kg of maize using the group machines, about 62% of their total maize production. Farmers also used manual methods (39.3%) and commercial services (9.4%) to shell their maize. The farmers had been shelling about 90% of their maize using manual methods (hands or sticks) before the introduction of the group machines. This percentage has now been reduced to about 25%. Farmers have therefore gained significant benefits in labor savings and drudgery reduction.

This sub-activity will be carried forward to the 2021-2022 work plan, the data analysis will be finalized, and a paper will be written.

[1] Michalscheck, M., Groot, J.C.J., Kotu, B., Hoeschle-Zeledon, I., Kuivanen, K., Descheemaeker, K., Tittonell, P., 2018. Model results versus farmer realities. Operationalizing diversity within and among smallholder farm systems for a nuanced impact assessment of technology packages. Agric. Syst. 162, 164–178. https://doi.org/10.1016/j.agsy.2018.01.028

Outcome 3: Farmers and other value chain actors have greater and equitable access to production assets and markets (input and output) through enabling institutions and policies

Output 3.1: *Improved policies and institutional arrangements to increase participation of farm families, especially women and youth in the output and input markets and decision-making are developed*

Activity 3.1.1: *Review existing policies and institutional arrangements affecting equitable access to production assets and markets.*

Sub-activity GH 3111-20: Strengthen the technical, managerial, and organizational capacities of the major actors in the small ruminant value chain through existent institutional structures such as Farmer-based Organizations (FBO), District Assemblies (DA), Community-based Organizations (CBO), Traders Associations, Transport and Input Dealers Association (Lead institution: CSIR- ARI)

Visit of the national director of the livestock value chains from Burkina Faso

The national director of the livestock value chains from Burkina Faso visited between 28 March 2021 and 1 April 2021. The team and the resource person visited the Navrongo livestock market in the morning on the first day to observe how the market operates. In the afternoon, the team presented the current state of the small ruminant value chain in Northern Ghana. The next day, the resource person presented how Burkina Faso developed its small ruminant value chain to the Innovation Platform. There was a workshop to identify policy recommendations, institutional arrangements, capacity-building activities, organizational mechanisms, and policy documents needed to develop the Ghanaian small ruminant value chain with increased participation of women and the youth. This meeting was attended by the team, the Municipal Director of Agriculture, and experienced farmers.

Launch of the Navrongo Innovation Platform in the Kassena Nankana municipality

On 4 March 2021, the livestock innovation platform organized its members to launch the platform in the Kassena-Nankana Municipality officially. Present were the value chain actors, the Municipal Agricultural Director, Agricultural officers, the project team, the Municipal Planning Officer (MPO), the Department of Cooperatives staff, and the media. The media professional was from the Ghana News Agency (GNA). In his welcome address, the Municipal Director of Agricultures reiterated that the existing livestock groups in the municipality had poor linkages. He tasked the platform to strengthen the linkages to the extent that a trader in the Accra market would avoid traveling to Navrongo market to buy animals by calling to request any number of animals needed to be sent to Accra. The project team leader mentioned some of the livestock value chain policies in Burkina Faso to encourage the platform actors. He said that by the time the platform will sustain itself, there would be no longer any need for the Ghanaian livestock traders to travel to Burkina Faso to buy animals.

During the launch, the executive members were elected to steer the innovation platform administration: the chairman, vice-chairman, secretary, assistant secretary, treasurer, organizer, and assistant organizer and several executive members, including producers and traders.

Partnership with Cowtribe

Cowtribe is a company that builds a logistics platform to aggregate last-mile farmer demand for livestock products and then deliver them to their farms. They focus especially on how to improve the vaccine delivery system in livestock production areas. It is a registered company of the Ghana Veterinary Council. Cowtribe organizes and links unemployed Veterinary technicians to livestock farmers for-profit and has a calendar for its vaccination activities. To tap their services, livestock farmers would have to first register by providing their demographic characteristics, including names, sex, farming experience, number of animals, and location, among others. The entry point to the communities is through the Village Savings and Loans Associations (VSLA) and farmer groups. Thus, farmers who are part of such associations are prioritized. To provide effective vaccines, Cowtribe has established cold rooms in all districts they are working in. Africa RISING communities in the Northern Region are already enjoying the services of Cowtribe as they work in Savelugu and Tolon districts, which are Africa RISING (AR) project districts. Cowtribe has promised to extend its work to all Africa RISING sites, particularly the Kassena-Nankana Municipal and Wa West district.

An evaluative survey concerning the sustainable indicators was performed among 44 farmers across the Navrongo and Wa sites. The survey covers the years 2019-2020 and 2020-2021. It is difficult to conclude since it has not been possible to get all data for 2021 since the year has not been finalized yet. Results are, therefore, preliminary and will be substantiated next year when more data will be available. The number of sheep and goats owned by the farmers seems to have dropped. Also, they sold fewer animals than last year. The soils tested by Africa RISING farmers seemed to have better quality, but the statistical significance has not been established yet. All the women replied that Africa RISING had improved their lives; they could now sell animals. Also, the fertility of women's crop fields is increasing.

This sub-activity will be carried forward into next year's work plan, the analyses will be completed, and more partnerships will be explored and established to strengthen the innovation platforms.

Sub-activity GH3121: Assess the inclusiveness of women and youth within the vegetable production value chain to enhance vegetable production among smallholder farmers (Lead institution: WorldVeg)

The goal is to expand women's and youth's incomes and achieve a more balanced value-added appropriation. The involvement of youth and women in the value chain of high-value crops such as irrigated vegetables can sustain production and reduce poverty for poor households. Therefore, there is a need to include both groups within the Upper East and Northern Regions of Ghana as vegetable value chain key players to establish long-term relationships and transform small-scale vegetable production into sustainable businesses. Surveys were conducted in 15 communities (400 respondents in the Northern, Upper East, Upper West) to understand vegetable farmers' constraints in assessing seeds and other inputs within the vegetable value chain and Vegetable seed system. Data was collected and analyzed using SPSS V 25.

Men, women, and youth occupy different positions in the value chain. Men are more engaged in agro-dealing, women are mostly involved in processing and trading, and the youth are in production and transport (see table 16).

Table 16. The representation of men, women, and youth in the different links of the value chain

The direct value chain links	Men (%)	Women (%)	Youth (%)
Production	15	5	80
Agro-dealing	95	4	1
Processors	15	80	5
Traders	-	100	-
Transportation	-	5	95

The three groups ranked the challenges encountered in the vegetable value chain, reflected in table 17. The challenges between the groups are different. E.g., women consider the lack of access to land as a major constraint, which is probably why only 5% is active in production. All mention some constraints, for example, water, difficult access to the market, and lack of access to seed.

Table 17. Constraints on a scale of 1-5 encountered within the value chain

Constraints	Men	Women	Youth
Lack of water	1st	3rd	2nd
Difficult access to market	5th	2nd	5th
Lack of access to tractor services	-	-	-
High cost of fertilizer	3rd	-	-
High cost of insecticide	-	-	
Lack to credit	-	-	4th
Pest/diseases	4th	4th	-
Lack of access to seed (poor quality, expensive, poor availability)	2nd	5th	3rd
Lack of buyer	-	-	-
Lack of irrigation	-	-	1st
Lack of organization	-	-	-
Scarcity of land	-	1st	-

Two meetings were dedicated to this sub-activity in May 2021 in Tamale and Navrongo to:

1. Share knowledge and highlight strengths and shortcomings in irrigated vegetable value chain development
2. Determine alternative solutions/approaches that could have addressed the deficiencies/constraints better
3. Initiate local partnership between seed regulators and seed cooperatives/enterprises to register and produce farmers' preferred varieties of seeds derived from the Africa RISING project.
4. Create sustainable linkages between small-holder vegetable farmers and key actors in the value chain

Different stakeholders identified within the vegetable value chain participated in both meetings. Among the participants were representatives from the Ministry of Food and Agriculture, Metropolitan assembly, Agro inputs, and agro machinery dealers, University for Development Studies, Bolgatanga Technical University, Vegetable marketers and trader's association, Women in Agriculture development, private organizations, Tractor operator's union, financial

institutions, and smallholder farmers. The objectives were successfully met with a network of actors mapped, and smallholder farmers now have access to the services they require.

This sub-activity has not finalized all activities yet and will be carried forward to next year.

Sub-activity 3.1.2.2-20: Assess women and youth participation in maize and small ruminant value chains in the project communities and the markets that link to the communities (Lead institution: IITA)

GH1112-20, which concerns maize leaf stripping, fodder cultivation, the introduction of feed troughs, N-optimization in maize-based cropping systems. It investigates the gender and intergenerational relations in the maize livestock value chains in communities in which Africa RISING is active and in the markets these communities are linked to. Write-up of the results of the gender aspects related to maize the leaf stripping intervention in Ghana (GH 1123-20) has been completed. A manuscript titled "Developing gender-transformative innovation packages for sustainable intensification: The case of maize leaf stripping in northern Ghana" has been submitted to the Journal of Rural Studies. Data collection at all nodes has been completed to assess the opportunities and constraints for women and youth participation (and benefits) in the small ruminant value chain. Respondents comprised livestock keepers, feed and food vendors, animal health providers, traders, butchers, and feed trough manufacturers. Preliminary results were presented at the annual conference of the CGIAR Gender Platform "Cultivating Gender Equality" in October 2021. Title: "The woman has no right to sell livestock": The role of gender norms in Northern Ghana's small ruminant value chains and implications for transformative interventions. Results indicate that men and women respondents, to a great extent, agree that married women are generally not capable of making important decisions by themselves and should not leave home without their husbands' permission.

Furthermore, it was seen as unacceptable for women to take up roles in the trade of livestock. Other aspects were more controversial, such as whether women may reveal their livestock ownership or contribute substantially to household income. Further gender analysis will focus on how by-laws, norms, and policies restrict or enable non-production actors. The completed study will offer specific recommendations for gender-transformative interventions in northern Ghana's maize and small ruminants value chains.

Output 3.2. *Options to increase access to production assets and increase participation in decision-making by women, youth, and other vulnerable groups.*

Activity 3.2.1: *Identify constraints and opportunities for increasing women and youth access to production assets in the target area.*

Sub-activity GH3211-20: Evaluate risk and vulnerability as well as resilience within maize-cowpea living mulch systems in relation to smallholder farmers' livelihoods (Lead institution: IITA)

This sub-activity links with sub-activity GH1212-20, which assesses the impact of soil and water conservation interventions. This sub-activity complements the former in that it evaluates the risk, vulnerability, and resilience within the maize-cowpea living mulch systems in relation to smallholder farmers' livelihoods. This allows us to explore risk and resilience issues within maize-cowpea living mulch systems and how to reduce the vulnerability of smallholder farmers while increasing livelihood opportunities. The work conducted for this sub-activity went broader

beyond cowpea-living mulch and encompassed other interventions through a region-wide survey with 545 respondents. Work from this study has been synthesized into a manuscript that is going through an internal evaluation process.

To develop practical, measurable resilience-building strategies, we considered the complex interactions between risks, people, and the socio-ecological systems in which they live. These interactions occur at various spatial and temporal scales and are inherently dynamic. Thus, when shocks hit a system such as farming systems for Africa RISING farmers, they do not occur in isolation; instead, they interact with multiple factors that can compound their impact and provoke downstream effects. Understanding social-ecological systems, for instance, requires understanding how people think, engage with one another and their environment, and react to and affect changes from the local level to the community, regional and national level. A synthesis on resilience in smallholder farming systems has been prepared. The Online version of the Synthesis can be accessed here. In addition, a Journal article that has gone through the internal review is currently being prepared for submission to Agricultural Systems Journal article can be accessed HERE.

Outcome 4: Effective partnerships are built with farmers, local communities, and research and development partners in the private and public sectors to ensure delivery and uptake at scale of SI, technologies, innovations, and practices.

Output 4.1: *Alliances and effective partnerships developed between farmers, local communities, and research and development agents in the public and private sectors to enable the release, dissemination, and adoption of proven technologies and practices to scale.*

Activity 4.1.1: *Conduct cost-benefit and gender analysis coupled with other socioeconomic analyses to identify and quantify adoption constraints and opportunities for different farmer contexts.*

Sub-activity GH4111-20: Conduct simulation and other socioeconomic analyses of selected SI technologies/practices for different farmer contexts to better understand the adoption potential of these proven technologies and opportunities for scaling up (Lead institution: STEPRI).

This study focused on two activities a) the dissemination exercise and b) additional analysis of representative technological pathways and gender-disaggregated analysis on farmer adoption decisions concerning Africa RISING SI practices/ technologies. The technologies considered were: 1) row planting of maize and intercropping with cowpea or beans, b) burying of fertilizer along the crop root, 3) use of cover crops and living mulch, 4) use of improved varieties that are early maturing and drought-resistant, 5) maize leaf stripping. The underlying assumption is that male and female smallholder farmers have, amongst others, different socio-economic, cultural, educational, and household positions, which likely cause a difference in technology uptake. The findings will inform the policymakers on how to develop pathways for SI technology dissemination, thereby taking the gender component into account.

The exercise took place in 16 communities in three regions in Northern Ghana. It focused on the state of affairs in mechanization, sustainable intensification practices, impact of sustainable practices, input and output markets. In total, 292 male and 229 female smallholder farmers participated in the exercise. The quantified and analyzed results indicated that smallholder farmers would like to be familiar with simple multi-functional small agricultural machines. The experience with the maize shellers was positive, but a lack of knowledge on how to repair and get the spare parts (also for the ploughs) was an issue. Concerning the sustainable intensification practices, the farmers indicated they lacked knowledge yet indicated that adoption has been beneficial and has resulted in improved nutrition. The results also showed that farmers without access to extension services were 28% less likely to access input markets. Additionally, farmers without access to financial services were 25% less likely to have access to the input market. Farmers without access to storage facilities and/or market information and/ or having farmers at large distances were more likely to sell at farmgate or the village market. It was striking that only 18% of the farmers had access to a guaranteed market; they seldom used written documents and contracts. The study suggests multiple potential solutions to solve these problems.

The gender-disaggregated analysis on farmer adoption decisions concerning the five technologies indicated differences between male and female farmers. Female farmers had less access to formal education, were less likely than men to be married, were more likely to be a member of an FBO, were more likely to have fields further away from their residences, were more likely to have smaller farms, and relied much more on hired labor than male farmers who relied mainly on family labor. No differences were found concerning the variable's access to extension services and perceived ease in adopting the technologies. The probit regression analysis indicated that for the females, three variables seemed to be statistically significant in predicting the adoption of sustainable intensification technologies: increasing age, being a member of an FBO, and farm size. All three positively impacted the likeliness of adoption, of which members of an FBO was the most important one that increased the likelihood of adoption by 69%. Membership facilitates access to loans, networking, information and provides peer influence. The probit regression analysis indicated that for the male farmers, seven variables seemed to be statistically significant in predicting the adoption of the sustainable intensification technologies: married status, formal education, membership of FBO, perception of ease of adoption, distance to the farm, the amount of credit received and access to extension services. Also, for men, the membership of an FBO was likely to increase the adoption by 65%. Group membership or belonging to a farmer-based organization (FBO) and ease of adopting the technologies (PEC) are the only factors that promote technology adoption among both males and females. This gives the female farmers an advantage since they are more likely than men to be members. The policy briefs reflecting the recommendations are in the process of drafting and will be made available soon.

Sub-activity MA4111-20: Determine farmers' preferences of technology attributes in cereal-legume systems of southern Mali (Lead institution: ICRISAT).

The study's objectives are first to identify important traits associated with sorghum technologies as perceived by farmers in southern Mali. Second, to assess the differences in the technology preferences among farmers concerning gender and other farmer technologies. The study uses two types of data including household survey data and focuses group discussion data.
Data from focus group discussions have been used to design the questionnaire for the household survey. The household survey started in February 2021 in Bougouni and Koutiala

districts in southern Mali. The survey is planned for 15 villages, and so far, the work has been completed with 442 out of 600 farmers producing sorghum, with on average 30 farmers surveyed per village. The remaining survey will be completed in the current month of March. The households surveyed participated in the baseline survey conducted in 2012 before starting the Africa RISING project in Mali. Other households in the same village replaced households that were absent or not available. Data collected were gathered on attributes related to the experimental choice approach (sorghum grain yield, yield instability, soil fertility outcome, nutrition outcome, labor requirement, and sorghum fodder yield), agricultural land, soil conservation, use of agricultural inputs (seeds, fertilizers, pesticides, herbicides, etc.), livestock ownership, extension service support, off-farm income, assets and services, food security, and household welfare.

Results from summary statistics on farm households' characteristics in the study area by the social network of households and farm household typology revealed notable differences between households. Those with strong social networks (participate in social groups and/or have a member in a community-based farmer research group) and those with weak social networks (do not participate in social groups and/or have no member in a community-based farmer research group). As expected, households with strong social networks were significantly better off regarding access to services and institutions, including crop insurance, contract farming, social safety net programs, and agricultural advice. A significantly higher share of such households are aware of biofortified sorghum and cultivate and consume it. They appear to be wealthier (operate a significantly larger parcel of land), have significantly more grain yield, and constitute a significantly larger share of households that receive off-farm income. On the other hand, a significantly larger share of households with a weak social network experienced crop failure in the past five years and grew sorghum solely for food.

Analysis on trade-offs highlighted that farmers value grain yield about seven times as much as they value fodder yield. This suggests that despite the importance of increased fodder yield for livestock production in the research area, farmers place more weight on grain yield in considering uptake sustainable sorghum-based cropping systems. This is probably because of the food security role of sorghum in the research area, as a large share of households grows sorghum solely for food.

Sustainable sorghum-based cropping system options with an increased nutrition outcome were valued more than those with a neutral nutrition outcome. Farmers valued increased nutrition outcomes associated with the uptake of sustainable sorghum-based cropping system options about 25 times as much as they valued grain yield. This suggests their increasing awareness of the importance of nutrition security beyond the traditional drive for food security. Similarly, an increased soil fertility outcome was valued more than a neutral soil fertility outcome, with 21 times more weightages given to increased soil fertility outcomes than grain yield. This suggests that farmers are interested in sorghum-based cropping system intensification options that can improve soil health (associated with long-term benefits) over intensification options that can only offer yield gains (short-term benefits).

Sub-activity GH4112-20: Evaluate the impact of SI practices on household welfare, poverty, perceived shock, the environment, and food and nutrition security in northern Ghana (Lead Institution: ZEF)

This study concerns the work of a Ph.D. student. Many impact studies on technology adoption focus on yield and gross income. However, relying on gross income alone for policy decision-making towards scaling out agricultural innovation may lead to spurious and inaccurate decisions. This is because farmers can easily increase income by reallocating resources from other economic activities, given the technologies they adopt. Also, differences in variable costs and outputs associated with crop production suggest that gross income and yield alone cannot be relied upon for policy decision-making. Therefore, ascertaining the benefits of technology on household income would require estimating farmers' return on investment in addition to gross income. Literature on adoption in sub-Saharan Africa (SSA) has documented several factors (e.g., poor road network, inadequate use of fertilizer, lack of access to new agricultural inputs) that cause low adoption of new agricultural technologies and practices. The literature on adoption focuses less on the type of farm households that need to be targeted during scaling-up. Identifying the farm household type that needs to be targeted during the scaling-up of agricultural technologies and practices is important since the farming system in SSA is very heterogeneous in terms of farmers' resource endowment and agroecological conditions. Thus, failure to identify the farm household type that needs to be targeted during scaling-up may lead to the mistargeting of new agricultural technologies and practices. This study examines the effects of farmers' resource endowment and unobserved factors on the marginal and average benefits of adopting SI practices and intends to identify the potential farm types and households likely to benefit at scale. What factors influence the farmer's decision to adopt a sustainable intensification (SI) technology? What are the effects of adopting SI practices on 1) Crop yields; 2) Household welfare; 3) Return on investment; 4) The environment; 5) Food and nutrition security; a6) Poverty rates; and 7) Perceived shocks? And what is the effectiveness of using nudges (e.g., accessible inputs, training) to induce the adoption of SI practices? The study uses data from the Africa RISING communities in northern Ghana.

The preliminary results show that group membership and information from an extension agent or NGO increases farmers' propensity to adopt, whereas information from other farmers decreases the tendency to adopt. The findings further indicate that households with more members and more productive assets are more likely to adopt. Finally, the data suggest that farm households with large plot sizes are less likely to adopt. It has been established that adopting sustainable intensification practices (SI practices) increases farmers' maize yields and net incomes (see table 18). Second, farm household resource endowment and unobserved factors (e.g., managerial skills) influence the marginal and average benefits of adopting SI practices. Third, scaling-up SI practices should be targeted due to differences in farmers' resource endowment.

A manuscript has been drafted and submitted to the European Review of Agricultural Economics.

Table 18. Average effects of adopting SI practices

Parameter	Maize yield (Kg/ha)	Net returns of maize and legume yield (GHS/ha)
	(1)	(2)
ATE	285.460 (312.018)	1906.905* (1215.914)
TT	961.320** (456.968)	3138.313** (1818.570)
TUT	-258.339 (539.176)	910.919 (1958.646)
Observations	669	

Notes: Bootstrap standard errors in parentheses***, **, * significance at 1,5 and 10 percent levels, respectively. 1 USD= GHS 5.4. ATE, TT, TUT denote the average treatment effect, the treatment effect on the treated, and the treatment effect on the untreated, respectively.

Activity 4.1.2: *Map and assess relevant stakeholders to establish a dialogue to explore mutual synergies for scaling the delivery of validated technologies.*

Sub-activity GH4121-20: Utilize ICT and GIS tools as a means to share information (agronomic, climatic, and market services) and scale-out Africa RISING technologies in collaboration with strategic partnerships in the region (Lead institution: IITA)

This sub-activity is an integrating activity across the interventions being promoted in Africa RISING Ghana. It entails working closely with other partners for packaging the right messages and timing of message delivery to the end-users. It also involved awareness-raising on the role and benefits of ICT messaging for both farmers and extension officers. As exemplified by Figure 16, we offer a bundled approach for smallholder farmers with services and messaging tailored to crop agronomy, climate services, market information, and post-harvest management practices. The ESOKO team helps to provide the ICT messaging.

The Project team developed a KASA assessment framework to evaluate the impact level of the different interventions that were being promoted. In the framework tabular matrix, we tested five overarching parameters for our farmers: field preparation and layout, Good agronomic practices, soil and water conservation, cropping calendar exposure, and the usefulness of ICT messaging.

Knowledge Attitude Skills Aspirations (KASA) assessment
Category: Agricultural Extension Agents/Technical Officers □ Farmer □
Code: ……..

Type of Training	KNOWLEDGE		ATTITUDE		SKILLS		ASPIRATIONS	
	Before Training	After Training	Before Training	After Training	Before Training	After Training	Before Training	After Training
Field preparation and layout								
Good agronomic practices								
Soil and Water Conservation								
Cropping calendar exposure								
The usefulness of ICT messages								

Ratings: Very poor - 1; Poor - 2; Average - 3; Good - 4; Very good - 5

Figure 16. KASA assessment framework

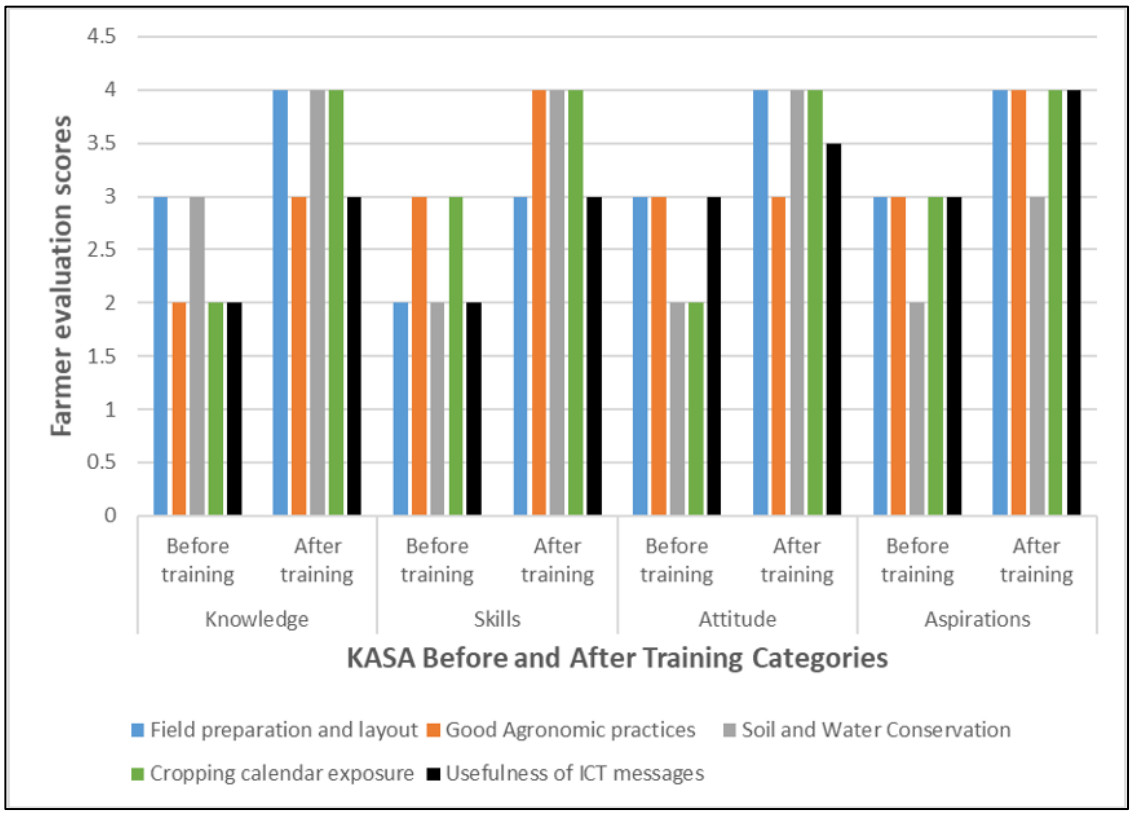


Figure 17. The results from the KASA assessment framework

The results depicted in Figure 17 show the knowledge, attitude, skills, and aspirations for the five parameters considered (field preparation and layout, good agronomic practices, soil and water conservation, cropping calendar exposure, and the usefulness of ICT messaging) all showed a positive trend. A key message from this study showed that information strongly empowers farmers, given the baseline data from our farming communities. We compared farmers with formal education exposure to those who did not have formal education exposure. Still, both categories had received training on-field preparation and layout, good agronomic practices, soil, and water conservation, using the cropping calendar chart, and using information from ICT messaging. Our results indicated stark differences between the farmers who did not have formal education and those who were educated before training. However, there was no difference in the KASA results after both groups received training.

Further efforts were taken to tease apart why the scores were as reflected, and these are currently being incorporated in the manuscript under preparation. There were numerous training events provided to farmers on soil and water conservation and on cropping calendar advisories. This was complemented with a KASA (Knowledge, Attitude, Skills, and Aspirations) analysis framework on ICT and GIS with extension workers and farmers to evaluate the effectiveness of the respective capacity-building activities provided to the project beneficiaries.

During the reporting period, the MWANGA Platform supported Africa RISING activities by disseminating key messages to farmers. Currently, the platform has a membership of 300 farmers within the three Regions of Northern Ghana. This allowed farmers to access information that improved their decision-making about which crops to grow, when to grow them and where

to sell them. The information channeled through Esoko is timely; for example, during this period, it has provided a direct linkage to market outlets that offer reasonable prices for farmer products. The platform also keeps farmers aware of weather forecasts, appropriate times for fertilizer applications, and weeding practices to maximize their yields. (https://app.esoko.com/).

Output 4.3. *A framework for monitoring and evaluating technology adoption, and technology-associated risk accessible to the project team and scaling partners*

Activity 4.3.1: Monitor and modify the progress of technology adoption process towards scaling.

Sub-activity GH4311-20: Matching agricultural technologies to farms and their context (Lead Institution: WUR)

This sub-activity provides a brief update on FarmMATCH work. A software engineer has been working with researchers of IITA and IFPRI to prepare data from ARBES and GIS maps and analyze these data for their use in FarmMATCH. To test the FarmMATCH algorithm, we have converted the ARBES data files for Ghana into a relational database (RDB). A draft manuscript has been written, revised, and re-submitted for publication.

Sub-activity MA4311: Sustainable intensification in mixed crop and livestock systems and natural resource governance in southern Mali – Synthesis of interventions (Lead institution: ILRI)

This sub-activity aims to prepare an overview of various natural resource governance interventions since 2013 in the Africa RISING intervention communities in Bougouni and Koutiala, including pertinent recommendations.

Some general conclusions about the usefulness of the formalized local conventions, based on group discussions, are reflected in table 19.

Table 19. The general usefulness of the formalized local conventions according to the participant at the Group Discussions

Usefulness	Dieba	Sirakele	Zanzoni
1. Fundamental tool for natural resource management in the community	4	4	4
2. Facilitate conflict management	4	4	4
3. Define rules and procedures for the use of natural resources	4	4	4
4. Reduce natural resource degradation	4	3	4
5. Clarify roles of different stakeholders in the management of natural resources in the community	3	4	4
6. Protect the interest of the community in managing their natural resources	3	2	3

7. Facilitate land use planning for the community	2	3	2
8. Encourage external investment for the conservation and use of community natural resources	2	2	2

The respondents rated the general usefulness of the formalized local conventions as a fundamental tool for natural resource management very high. The formalized local convention was also beneficial for conflict management, defining rules and procedures for using natural resources, and reducing natural resource degradation. The level of enforcement of the formalized local conventions was perceived to be generally strong in all the three study sites regarding the management of communal grazing areas, presence of transhumance in the village territory, management of community forests, harvest of non-timber forest products, control of bush fire, and hunting of wild animals.

The level of enforcement tended to be location-specific for managing transhumant corridors, access to land for cultivation, grazing of crop residues, and management of conflict between farmers and transhumant herders. The respondents in all the three study sites completely agreed with the perceived benefits of the formalized local conventions such as amelioration of the management of the natural resources in the community, reduction in conflict relating to natural resource use, facilitation of the elaboration of long term plan for natural resource management, access to technical and institutional support, strengthening of the decision making by the population on their natural resources, and awareness building of individual rights, duties, and benefits. The respondents agreed with the problem of lack of incentive to respect the local conventions.

The main conclusions from the survey on the perceived impact of formalized local conventions on natural resource management in Southern Mali.

- The formalized local convention was highly useful for conflict management, the definition of rules and procedures for using natural resources and reducing natural resource degradation.
- The level of enforcement of the formalized local conventions was perceived to vary depending on the natural resource management issue and location. Generally, the enforcement of the formalized local conventions was perceived to be strong in all the three study sites regarding the management of communal grazing areas, presence of transhumance in the village territory, management of community forests, harvest of non-timber forest products, and control of bush fire. However, the level of enforcement tended to be location-specific for managing transhumant corridors, access to land for cultivation, grazing of crop residues, and management of conflict between farmers and transhumant herders.
- The perceived benefits of the formalized local conventions according to the respondents in the three study sites included improvements in the management of the natural resources in the community, a significant reduction in conflict relating to natural resource use, facilitation of the elaboration of a long-term plan for natural resource management, access to technical and institutional support, and strengthening of the decision making by the population on their natural resources.

This sub-activity is not taken forward since ILRI is not a partner in next year's work plan.

Sub-activity MA4312-20: Assess the impact of Innovation Platforms on SI technology uptake in Africa RISING interventions communities (Lead Institution: AMEDD)

The partner reported no major work done during this period. They are working on a publication on the impact of innovation platforms in technology dissemination on strengthening and sustaining multi-stakeholder innovation platforms.

Sub-activity MA4313-20: GIS mapping of implemented technologies across different agro-ecologies and gender influence in technology adaptation and use in Bougouni and Koutiala districts of Mali (Lead institution: AMEDD)

The partner had not planned much work for this reporting period. A manuscript on gender dis-aggregated technology adoption for two agro-ecologies in Koutiala and Bougouni districts is under preparation.

This sub-activity is being carried forward since it was decided to include the analysis of rainfall onsets, cessation, and length of the rainy season from the long-term data obtained from the Sikasso, Segou, and Mopti regions. This would improve the content of the manuscript under development.

Sub-activity MA4411: Manage the operations of four technology parks as hubs for innovation, research, extension, advisory, coordination, and demonstration in Bougouni

All technologies tested and validated in the four technology parks (Table 20) were successful, and data were collected to the required standard based on the stated protocols. A total of 332 farmers (30% women) participated in the technology validation experiment in the four technology parks. In addition, a farmers' field day (FFD) was conducted in the four technology parks of both districts (Bougouni and Koutiala). In each site, a maximum of 30 participants was allowed for FFD to minimize the impact of the covid-19 pandemic. Hence a total of 120 participants was present for the FFD in the four technology parks. The visited technologies in the parks include; contour bunds with fast-growing tree species, dual-purpose sorghum varieties, sorghum hybrids (Fadda, Tieble, and Soumba), different technologies of ISFM, fodder species that include Brachiaria, Mucuna, and cowpea Sankarannan. Participants also visited technologies, including vegetable sack gardens and postharvest technologies. A photo report can be accessed through the link below: https://africa-rising.net/photo-report-west-africa-project-partners-cap-off-2020-with-farmers-field-day-events-in-northern-ghana-and-southern-mali/?utm_source=feedburner&utm_medium=email&utm_campaign=Feed%3A+agintensificationafrica_news+%28Africa+RISING+news%29

Table 20. Africa RISING technologies tested and validated at the technology parks in Bougouna and Koutiala 2020-2021

Technology Parks	Validated technologies	Number of farmers participating
Madina, Flola, M'Pessoba and N'golonianasso	Contour bunding associated with agroforestry options	28
	Fertilizer sources combined organic (cow and poultry manure) and inorganic fertilizer application on three sorghum varieties (Soumba, Fadda, and Tieble).	14
	Four high yielding dual-purpose sorghum hybrids	48
	High-performing vegetable varieties with farmers' preferred traits. These include three tomatoes, 3 African Eggplant, five vegetable cowpea, and six onion varieties	65
	Fodder species that include Brachiaria, Mucuna, and cowpea Sankarannan	48
M'Pessoba	Vegetable sack gardens	60
M'pessoba and Madina	Compost type1: 1 ton cotton stem+ 200 kg cattle manure + 50 kg dry leaves + 50 kg ash + 50 kg millet hull. Compost type 2: 2 tons cotton stem + 200 kg cattle manure + 50 kg dry leaves + 50 kg ash + 50 kg millet hull	22
Madina	Zero Energy Cooling Chamber (ZECC)	12
Madina and N'golonianasso	Improved water management practices with the use of solar irrigation pump and drip irrigation system	35

Two main training on forage production and sorghum fertility management were conducted in the technology parks of Bougouni and Koutiala for a total of 76 farmers (Table 21).

Table 21. Type/title of training, where, when, number, and category of people trained

Title	Location	Date	Number	Category
Forage production	M'Pessoba Technology Park	6 – 8 July 2020	30 participants (7 females)	Students from agricultural technical college (Centre d'Apprentisage Agricole) M'Pessoba
Sorghum fertility management (Soumba and Fadda)	M'Pessoba and N'golonianasso Technology Parks	June 29-July 1st	24 participants (11 females)	Farmers from M'pessoba, Zanzoni, Sirakele, N'golonianasso and Nampossela
Sorghum fertility management (Soumba and Fadda)	Madina technology park	02-3July	22 participants (6 females)	Farmers from Dieba, Sibirila, Flola, and Madina

Communication and knowledge sharing

The main communication channels supported during the reporting period were:

- Wiki internal workspace: http://africa-rising-wiki.net/Home
- Project updates on the program website: https://africa-rising.net/
- A Yammer network for internal updates
- Photos: https://www.flickr.com/photos/africa-rising/
- Repository: https://cgspace.cgiar.org/handle/10568/16501

The stories listed below were published and disseminated to stakeholders concerning different project activities and outputs during the reporting period.

- BRIEF FOCUS: Cowpea living mulch for food security and soil health (20 July 2021)
- BRIEF FOCUS: Feed and health package for improved small ruminant production (15 July 2021)
- Building a better solar irrigation market in Ghana (8 July 2021)
- BRIEF FOCUS: Optimal spacing for groundnuts in smallholder farming systems (9 June 2021)
- Transforming crop residues into a precious feed resource for small ruminants in northern Ghana (9 April 2021)

The following meetings and events were held during the reporting period. The communications team supported some of these meetings and events through materials preparation, facilitation, etc.

- 01 Sept: West Africa Virtual Exchange Seminar (WAVES) - virtual, MS TEAMS
- 04 August: West Africa Virtual Exchange Seminar (WAVES) - virtual, MS TEAMS
- 07 July: West Africa Virtual Exchange Seminar (WAVES) -virtual, MS TEAMS
- 02 June: West Africa Virtual Exchange Seminar (WAVES) - virtual, MS TEAMS
- 26 - 27 May: West Africa Review and Planning meeting - Hybrid [virtual and in-person]
- 6 - 7 May: Stakeholder consultative and planning meeting by WorldVeg in Tamale and Navrongo
- 05 May: West Africa Virtual Exchange Seminar (WAVES)

Peer reviewed journal articles

- Minh, Thai Thi; Osei-Amponsah, Charity. 2021. Towards poor-centered value chain for sustainable development: a conceptual framework. Sustainable Development, 14p. (Online first) [doi: https://doi.org/10.1002/sd.2220]
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- Steps to boost sorghum productivity in the savannah and Sahelian regions of Mali (https://www.slideshare.net/africa-rising/2305-249618456)

Project logframe summary

We present the outcomes, outputs, and activities of Africa RISING West Africa Project Phase 2 using a logframe overview that can be accessed at this link:
http://africa-rising-wiki.net/images/0/06/Project_logframe_overview.docx